DESCRIPTION

CANCER GENE THERAPEUTIC DRUG

Technical field

[0001] This ~~invention~~disclosure relates to a cancer gene therapeutic drug, and a therapeutic method of using a cancer gene ~~therapeutic method using the~~ as a therapeutic drug.

Background art

[0002] Recently, ~~a~~ cancer gene therapy has received ~~been focused~~ attention as a ~~for~~ cancer therapy. ~~A and a~~ variety of gene therapies have been proposed for testing and ~~their~~ some clinical trials have been conducted to test their effect~~carried out~~. Among them, a clinical trial was performed by Freeman (Freeman, SM, et al., The treatment of ovarian cancer with a gene modified cancer vaccine: a phase I study, Hum Gene Ther., 1995 July 6(7):927-39) to test ~~of~~ a cancer gene therapy using carrier cells, ~~was performed by Freeman *et al.*,~~ This cancer gene therapy used~~s~~ an ovarian cancer cell~~s~~ (PA-1) with a HSV-tk gene from a ~~by~~ retrovirus as the carrier cell. ~~9~~ The ~~and its~~ clinical trial~~s~~ tested it for ovarian cancer therapy, as well as, malignant mesothelioma therapy ~~have been carried out~~ (see Paul Schwarzenberger, P., et al., Clinical Protocol The Treatment of Malignant Mesothelioma with a Gene Modified Cancer Cell Line: A Phase I Study, Human Gene Therapy, November 20, 1998, 9(17): 2641-2649 Human Gene Therapy, 9, 2641 - 2649, 1998~~non-patent literature Nos. 1 and 2 shown later~~). Culver (Culver, KW, et al., In vivo gene transfer with retroviral vector-producer cells for treatment of experimental brain tumors, *Science* 12 June 1992 256: 1550-1552) *et al.* used the mouse cell NIH-3T3 ~~cells~~ as the carrier cell~~s~~ and conducted ~~performed~~ a clinical trial to test it against a ~~for~~ cerebral tumor ~~(see non-patent literature No. 3 shown later)~~. However, ~~i~~its application for human cancer therapy, ~~however,~~ requires human derived cells as the carrier cells.

[0003] A gene therapy using the ovarian cancer cell~~s~~ PA-1 as the carrier cell~~s~~ was also carried out ~~by Coukos *et al.*,~~ (Coukos, G., et al., Use of Carrier Cells to Deliver a Replication-selective Herpes Simplex Virus-1 Mutant for the Intraperitoneal Therapy of Epithelial Ovarian Cancer, Clin. Cancer Res., 1999 5: 1523-1537~~see non-patent literature No. 4 shown later~~). This gene therapy uses ~~constructs~~ an oncolytic virus, ~~which~~ specifically

proliferates in tumor cells. ~~and t~~The virus is infected into the carrier cells (producer cells) and then the infected carrier cells are administered into the tumor site. Herpes simplex 1 (HSV-1) is used as the oncolytic virus. In an animal experiment, the infected carrier cells are injected their intraperitoneally ~~administration was performed~~ into a nude mouse model with ovarian cancer transferred to the peritoneal cavity (~~see~~ International Publication No. 99/45783 (pamphlet) and International Publication No. 01/23004 (pamphlet)~~patent literature Nos. 1 and 2 shown later~~).

The ~~[0004] Above-mentioned~~ ovarian cancer cells PA-1 show the ability to highly proliferate~~ing ability~~ and ~~can~~ be easily manipulated, but they have a drawback of being fragile~~ity~~ with a small cytoplasm. Therefore, introduction of the HSV-tk gene by retrovirus gives little expression of the HSV-tk gene in the tumor site and no satisfactory antitumor effect was obtained against ovarian cancer or malignant mesothelioma.

The use ~~[0005] Application~~ of PA-1 as the carrier cell~~s~~ in the cancer gene therapy with the oncolytic virus HSV-1 showed no significant antitumor effect in comparison to that of a therapy with only the oncolytic virus HSV-1. Repeated ~~No frequent~~ administrations of ~~can be performed in this~~e cancer gene therapy with a virus, virus cannot be conducted because of the production of ~~its~~ neutralizing antibodi~~es~~ in the blood against the cells. Using~~Application of~~ PA-1 cells results in little production of the virus due to its fragilit~~y e cells~~. The~~ir~~ cell disruption before infection to the target tumor cells by cell to cell interaction, and inactivation of the virus by ~~with its~~ neutralizing antibodi~~es~~ may produce ~~lead to~~ no significant antitumor effect.

~~[0006]~~ Furthermore, the patient's own cancer cells or fibroblasts could be ~~are~~ used as the carrier cells in a clinical trial of cellular immunological gene therapy. However, ~~T~~this procedure requires a long time to get a stable cell line and they are~~is~~ difficult to manipulate. ~~A~~In addition~~ally~~, ~~inconstant~~ individual differences occur with the ~~exists in~~ introduction of the gene and it is difficult to get a stable effect.

~~[0007] Non-patent literature No. 1: Human Gene Therapy, 6, 927-939, 1995~~

~~Non-patent literature No. 2: Human Gene Therapy, 9, 2641-2649, 1998~~

~~Non-patent literature No. 3: Science, 256, 1550-1552, 1992~~

~~Non-patent literature No. 4: Clinical Cancer Research, 5, 1523-1537, 1999~~

~~Patent literature No. 1: International Publication No. 99/45783, pamphlet~~

~~Patent literature No. 2: International Publication No. 01/23004, pamphlet~~

Disclosure ~~of the Invention~~

Problems to be Solved ~~by the Invention~~

[0008] The purpose of the present ~~invention~~disclosure is to solve the above problems and to find new carrier cells that exhibit~~ing~~ potent antitumor effects ~~with in the~~ cancer gene therapy using an~~the~~ oncolytic virus. Additionally, ~~further~~ to establish a new cancer gene therapeutic method exhibiting a very potent antitumor effect using the carrier cells etc., and to provide a new therapeutic method using a cancer gene therapeutic drug ~~used for the therapeutic method~~.

Means for solving the problems

[0009] The applicant~~inventors~~ of the present ~~invention~~disclosure have investigated solutions to ~~for solving~~ the above problems and found that; ~~those such a~~

~~s~~ (1) a more potent antitumor effect can be obtained by using a specific cell line as the carrier cell in comparison to that of a conventional carrier cell, and

(2) induc~~ingtion~~ and raising ~~of~~ a cytotoxic activity reaction through cytotoxic T lymphocytes (CTL reaction) within a living body by ~~through prior~~ administer~~ingration of~~ a virus for immunological treatment prior to ~~, followed by~~ administer~~ingration of~~ the carrier cell infected with an oncolytic virus, gives a very potent *in vivo* antitumor effect, and accomplished the present ~~invention~~disclosure.

[0010] That is, a cancer gene therapeutic drug of the present ~~invention~~disclosure (in other words, a drug kit for cancer therapy) is a combination of: a virus for immunological treatment to be administered for inducing a CTL reaction within a living body and for ~~to~~ administering ~~ration of~~ to the a carrier cell; and a carrier cell to be infected with an oncolytic virus before ~~the~~ administering to the living body~~ration~~ so as to make the oncolytic virus act on a tumor cell within the living body.

[0011] The virus for immunological treatment and the oncolytic virus of the present ~~invention~~disclosure are preferably selected from viruses, such as, adenovirus, herpes virus, lentivirus, ~~such as~~ HIV virus, retrovirus, reovirus, vesicular stomatitis virus (VSV), and any other oncolytic virus~~es~~. Among them, adenovirus gives a favorable results as shown later and c~~ouldan~~ be ~~prefer~~preferred for~~ably~~ use~~d~~.

[0012] Preferably, the oncolytic virus of the present ~~invention~~disclosure has a tumor specific promoter, according to the kind of cancers to be treated, including such as 1A1.3B

promoter (IAI.-3B promoter), midkine (MK) promoter, β-HCG promoter, SCCA1 promoter, cox-2 promoter, PSA promoter, or any other tumor specific promoters. Any oncolytic virus, capable of infection and proliferation in the target tumor cells, such as, adenovirus including its wild type, can be used in the present inventiondisclosure. Oncolytic viruses without a tumor specific promoter, such as an E1B gene deficient oncolytic adenovirus of ONYX Pharmaceuticals Inc. and an E1A gene partially deficient type Ad5-Δ24 adenovirus of University of Alabama at Birmingham (UAB), may be used.

[0013] The viruses for the immunological treatment used in the present inventiondisclosure are preferably a non-proliferative type and/or an inactivated type by UV irradiation, etc. Inactivation by UV irradiation, etc., may shorten the period between administering ration of the virus for immunological treatment and administering ration of the carrier cell.

[0014] The carrier cell of the present inventiondisclosure isare preferably selected from A549 cells, 293 cells, SW626 cells, HT-3 cells (HT-III cells) and any other human derived cancer cells or normal cells. Further, other commercially available cell lines, such as, PER.C6 cells of Crucell may be used. The Aabove mentioned A549 cells, 293 cells, SW626 cells and HT-3 cells gave favorable results as described later and are more preferable as the carrier cell. and A549 cells are particularly favorable among them.

[0015] The cancer gene therapeutic drug of the present inventiondisclosure (a drug kit for cancer therapy) is a combination of the virus for immunological treatment and the carrier cell, or further including the oncolytic virus to produce giving a kit composed of three members. AdditionallyMoreover, the kits may include one or more substances of (1)- (4) shown below.

(1) Atelocollagen

(2) GM-CSF (granulocyte-macrophage colony stimulating factor) expression vector to be infected to the carrier cell before administration

(3) Iron preparations

(4) Porphyrin compounds (e.g. 5-aminolevulinic acid: ALA)

[0016] Together with the administeringration of the virus for immunological treatment, or before or after it, administering ration of an irradiated tumor cell (a patient derived or a generally available one with similar antigen) is preferpreferredable for tumor vaccination (tumor immunization). The cancer gene therapeutic drug of the present inventiondisclosure may

include such irradiated tumor cell for the tumor vaccination.

[0017] The cancer gene therapeutic method of the present inventiondisclosure comprises a step for administering ration of a virus for immunological treatment to induce a CTL reaction within a living human body to administer ration of a carrier cell; and after a predetermined period, at least a single step for at least one of administering ration of a carrier cell to be infected with an oncolytic virus before the administering the cell to the living body ration so as to make the oncolytic virus act on a tumor cell within the livinghuman body.

[0018] The period from the administeringration of the virus for immunological treatment to the administering ration of the carrier cell in the cancer gene therapeutic method of the present inventiondisclosure is preferably set to be two weeks or more, and not more than 13 weeks (more preferably three weeks toor four weeks). Preferably, (1) the dose of the virus for immunological treatment may be set between about 10^5 viral particles and 10^{11} viral particles for a patient with antibodiesy negative to the virus, while between about 10^2 viral particles and 10^7 viral particles for a patient with antibodiesy positive to the virus, (2) the dose of the oncolytic virus by usingthrough the carrier cell may be set between about 10^9 viral particles and 10^{14} viral particles, (3) the infection rateconcentration of the oncolytic virus to the carrier cell may be set between about 0.1 viral particles/cell (hereinafter referred as "vp/cell") and 2,000 vp/cell, (mMore preferably between five vp/cell and 500 vp/cell).

[0019] In the cancer gene therapeutic method of the present inventiondisclosure, adoption of one or more steps of the following (1) to (5) is preferpreferredable:

-(1) Administration ofering the carrier cell by intratumor injection,

-(2) Administration ofering atelocollagen together with the carrier cell,

-(3) Administration ofering the carrier cell having been infected with not only the oncolytic virus and , but also a GM-CSF expression vector,

-(4) Administration ofering an iron preparation and/or a porphyrin compound [e.g. 5-aminolevulinic acid (ALA)] together with the carrier cell, and

-(5) Administration ofering a tumor cell for tumor vaccination together with, or before, or after, the virus for immunological treatment.

Effect of the InventionDisclosure

[0020] The cancer gene therapeutic drug of the present inventiondisclosure is a

combination of the two drugs composed of the virus for immunological treatment to be administered in advance and the carrier cell to be administered afterwards. Immunological treatment in advance by administration of ering the virus, such as, adenovirus and then administration of ering the carrier cell having been infected with the oncolytic virus provides a direct antitumor effect by infection of the oncolytic virus to the target tumor cells, and further induces the CTL reaction within the living body to the infected target cells, which provide sing a very potent *in vivo* antitumor effect.

[0021] Still further, use of a cell line such as, such as, A549 cells, which have with high antitumor effects both *in vitro* and *in vivo*, provides a more potent antitumor effect in comparison to those of conventional carrier cells.

Brief description of drawings

[0022] [Fig.Figure 1] The graph shows the results of the inhibitory effect on the proliferation inhibitory effect of to ovarian cancer cells HEY using various cell lines as carrier cells, expressed by cell numbers at IC_{50}.

[Fig.Figure 2] The graph shows the inhibitory effect results of investigation on of the proliferation inhibitory effect of oncolytic viruses without and together with carrier cells to the ovarian cancer cells HEY in the presence of antiviral antibodies, expressed by antibody titer of anti-adenovirus antibodies at IC_{50}.

[Fig.Figure 3] The graph shows the inhibitory effect results of investigation on the f proliferation inhibitory effect of oncolytic adenovirus infected carrier cells (such as 293 cells) to the ovarian cancer cells HEY in the presence of antiviral antibodies, expressed by antibody titer of anti-adenovirus antibodies at IC_{50}.

[Fig.Figure 4] The graph shows the inhibitory effect results of investigation on thef proliferation inhibitory effect to the ovarian cancer cells HEY using carrier cells of 293 cells, A549 cells, SW626 cells and HT-3 cells in the presence of antiviral antibodies, expressed by cell numbers.

[Fig.Figure 5] The graph shows the results of investigation of *in vivo* antitumor effect of oncolytic adenovirus infected carrier cells, using a tumor model with 10 - 15 mm massive tumor formed by subcutaneous transplantation of human ovarian cancer cells RMG-1 in a nude mouse.

[Fig.Figure 6] The graph shows the results of investigation of *in vivo* antitumor effect of

oncolytic adenovirus infected carrier cells, using a tumor model with 10 - 15 mm massive tumor formed by subcutaneous transplantation of human ovarian cancer cells PA-1 in a nude mouse.

[Fig. Figure 7] The graph shows the results of investigation of *in vivo* antitumor effect of a cancer gene therapeutic drug of the present inventiondisclosure using a subcutaneous tumor model mouse [(C57BL/6×C3/Hel) F1 mouse] with normal immune system.

[Fig. Figure 8] The Figure shows a photomicrographscopic observation of the cell fusion of A549 cells due to administration of adenovirus.

[Fig. Figure 9] The Figure shows a control photomicrographscopic observation of A549 cells without administration of an adenovirus.

[Fig. Figure 10] Graph (a) shows the results of investigation of midkine (MK) mRNA expression by RT-PCR in human surgical samples of 1 - 21; graph Figure 10 (b) shows the results of investigation of midkine (MK) mRNA expression by RT-PCR of four cell lines of malignant gliomas in a similar manner; and Figure 10 graph (c) shows the results of investigation of midkine (MK) expression in the above each of the above cell lines by Western blotting analysis.

[Fig. Figure 11] The graph shows the results of a comparative investigation of thea promoter activity in the above each of the above cell lines using two different length midkine promoters.

[Fig. Figure 12] Graph (a) shows a schematic structure of the oncolytic adenovirus, having the midkine promoter, designed in the present inventiondisclosure; and Figure 12graph (b) shows the results of investigation of E1A protein expression in the above each of the above cell lines infected with three kinds of adenoviruses by Western blotting analysis.

[Fig. Figure 13] Graph (a) shows the results of a comparative investigation of the inhibitory effect of cancer cell proliferation inhibitory effect with three kinds of adenoviruses; Figure 13 graph (b) shows the results of investigation of adenovirus E3 domain's influence on the inhibitory effect of proliferation inhibitory effect; and Figure 13 graph (c) shows the results of investigation of antitumor effect of an adenovirus in a nude mouse subcutaneous transplantation model with a tumor of 5 mm diameter.

[Fig. Figure 14] The graph shows the results of the antitumor effect of carrier cells infected with an oncolytic virus having the midkine promoter on a massive tumor with a 10 - 15 mm diameter, compared with administering ration of the oncolytic virus without carrier cells.

[Fig.Figure15] The graph shows the results of investigation of influence of Fe on the inhibitory effect of adenovirus AdE3-1A1.3B proliferation inhibitory effect of adenovirus AdE3-1A1.3B on the proliferation of ovarian cancer cells PA-1.

[Fig.Figure 16] The graph shows the results of investigation of influence of ALA on the inhibitory effect of adenovirus AdE3-1A1.3B proliferation inhibitory effect of adenovirus AdE3-1A1.3B on the proliferation of ovarian cancer cells PA-1.

[Fig.Figure 17] The graph shows the results of investigation of influence of the coexistence of Fe and ALA on the inhibitory effect of adenovirus AdE3-1A1.3B proliferation inhibitory effect of adenovirus AdE3-1A1.3B on the proliferation of ovarian cancer cells PA-1.

[Fig.Figure 18] The graph (a) shows the results of investigation of *in vivo* antitumor effect of a cancer gene therapeutic drug of the present inventiondisclosure (in the case of no UV irradiation treatment on the virus for immunological treatment) using a subcutaneous tumor model mouse [(C57BL/6×C3/He) F1 mouse] with normal immune system; and Figure 18 graph (b) shows the results of long term observation of survival rate of each mouse used for the experiment.

[Fig.Figure 19] The graphs show the interval between the results of investigation on the administration interval of from the virus for immunological treatment and the administration of to the carrier cell,, Figure 19graph (a) shows the observed results of tumor volume in each mouse; and Figure 19graph (b) shows the observed results of the survival rate in each mouse group.

[Fig.Figure 20] The graph (survival curve) shows the results of investigation whether the above administration interval in Figure 19 can be shortened by the usinge of adenovirus UV-Ad-β-gal inactivated by UV irradiation as thea virus for immunological treatment.

[Fig.Figure 21] The graph (tumor growth curve) shows the results of investigation on the administration rate of the above mentioned UV-Ad-β-gal used as the a virus for immunological treatment.

[Fig.Figure 22] The graphs show the examination results of tumor vaccination effect,, Figure 22 graph (a) shows the observed results of the tumor volume in each mouse; and Figure 22 graph (b) shows the observed results of survival rate in each mouse group. The number (n) of each mouse group was including five animals is shown by n = 5. In the Fig.Figure, control "SCC7" and "OVHM" show the results of subcutaneous transplantation of squamous epithelium

cancer cells SCC7 or ovarian cancer cells OVHM at a ~~rate~~concentration of 1×10^6 cells, followed by administeringration of AdE3-1A1.3B infected carrier cells A549 to mice. "OVHM-RT+ Ad-β-gal→SCC7, OVHM" shows the ~~results of~~ subcutaneous transplantation of SCC7 or OVHM, followed by administration ofering AdE3-1A1.3B infected carrier cells A549 to mice, after the mice had tumor vaccination with irradiated OVHM and ~~also~~ administration ofering Ad-β-gal for induction of the CTL to the adenovirus.

~~[Fig.~~Figure 23~~]~~ ~~The graph~~ (survival curve) shows the ~~examination results of~~ tumor vaccination effect with non-small-cell lung cancer A549 cells. The number (n) of each mouse group ~~was including~~ 10 animals ~~is shown by n = 10~~. In the ~~Fig.~~Figure, control, "OVHM", shows ~~the results of~~ subcutaneous transplantation of ovarian cancer cells OVHM at a ~~rate~~concentration of 1×10^6 cells, followed by administration ofering AdE3-1A1.3B infected carrier cells A549 to mice without tumor vaccination. "AdE3-1A1.3B-infected A549→OVHM" shows ~~the results of~~ subcutaneous transplantation of ovarian cancer cells OVHM at a ~~rate~~concentration of 1×10^6 cells, followed by administration ofering AdE3-1A1.3B infected carrier cells A549 to mice, after the mice were ~~had~~ subcutaneously vaccinated~~ion~~ with 1×10^6 irradiated ~~1×10^6~~ A549 cells infected with AdE3-1A1.3B.

~~[Fig.~~Figure 24~~]~~ ~~The graph~~ shows the ~~results of investigation whether the~~ death rate caused by side effects ~~with will be improved by~~ administration ofering atelocollagen together with the carrier cell. In the ~~Fig.~~Figure, "N" in ~~the~~ parentheses ~~is the represents~~ number of mice~~use~~.

~~[Fig.~~Figure 25~~]~~ ~~The graphs~~ shows the ~~results of investigation of~~ antitumor effect in the presence of anti-adenovirus antibodies ~~with by~~ 1 ~~to~~ ~~3 times~~ administrations of adenovirus Ad-β-gal without UV inactivation treatment. ~~,~~ Figure 25~~graph~~ (a) shows the ~~observed results of~~ tumor volume of each mouse~~;~~ and Figure 25 ~~graph~~ (b) shows the ~~observed results of~~ survival rate of each mouse group. A mixture of A549 cells and 293 cells was used as ~~the~~ carrier cells. The number (n) of each mouse group ~~including~~was five animals ~~is shown by n = 5~~.

~~[Fig.~~Figure 26~~]~~ ~~The graphs~~ shows the ~~results of investigation of~~ antitumor effect in the presence of anti-adenovirus antibodies ~~with by~~ 1 ~~to~~ ~~3 times~~ administrations of adenovirus Ad-β-gal without UV inactivation treatment. ~~,~~ Figure 26 graph (a) shows the ~~observed results of~~ tumor volume of each mouse~~;~~ and Figure 26 ~~graph~~ (b) shows the ~~observed results of~~ survival rate of each mouse group. A549 cells were used as ~~the~~ carrier cells. The number (n) of each

mouse group ~~including~~was five animals ~~is shown by n = 5~~.

~~[Fig.~~Figure 27~~]~~ ~~The graphs~~ shows the ~~results of investigation of~~ *in vivo* antitumor effect of administration ~~of~~ering the carrier cells (A549 cells) infected with ~~not only~~ adenovirus AdE3-1A1.3B ~~and but also a~~ GM-CSF expression vector, and administration ~~of~~ering atelocollagen together with the carrier cell. ~~;~~ Figure 27~~graph~~ (a) shows the ~~observed results of~~ tumor volume of each mouse~~;~~ and Figure 27~~graph~~ (b) shows the ~~observed results of the~~ survival rate of each mouse group. ~~In~~ In the ~~Fig.~~Figure, "×1", "×2" and "×3" in front of "Ad-β-gal" ~~represent~~show ~~1~~once, ~~2~~twice and ~~3~~thrice administrations of adenovirus Ad-β-gal, respectively. The number (n) of each mouse group ~~including~~was five animals ~~is shown by n = 5~~.

~~[Fig.~~Figure 28~~]~~ ~~The graphs~~ show~~s~~ the ~~results of investigation of~~ *in vivo* antitumor effect of intraperitoneal administration of an iron preparation together with the carrier cell. ~~,~~ Figure 28~~graph~~ (a) shows the ~~observed results of~~ tumor volume of each mouse~~;~~ and Figure 28~~graph~~ (b) shows ~~the observed results of~~ the survival rate of each mouse group. ~~In~~ In the ~~Fig.~~Figure, "×1", "×2" and "×3" in front of "Ad-β-gal" ~~represent~~show ~~1~~once, ~~2~~twice and ~~3~~thrice administrations of adenovirus Ad-β-gal, respectively. ~~The~~ The number (n) of each mouse group ~~including~~was five animals ~~is shown by n = 5~~.

~~[Fig.~~Figure 29~~]~~ ~~The graph~~ shows the ~~results of investigation of~~ radiation dose in radiation exposure to the carrier cell A549 using a nude mouse.

~~[Fig.~~Figure 30~~]~~ ~~The graph~~ shows the ~~results of investigation of~~ antitumor effect of carrier cells A549 irradiated with different doses, using (C57BL/6×C3/He) F1 ~~mice~~mouse with subcutaneous transplantation of OVHM.

~~[Fig.~~Figure 31~~]~~ ~~The graph~~ shows the ~~results of investigation of the~~ infection ~~rate~~concentration (amount) of the oncolytic virus to the carrier cell A549.

~~[Fig.~~Figure 32~~]~~ ~~The graphs~~ show~~s~~ the ~~examination results of~~ tumor vaccination effect with the ovarian cancer cells OVHM. ~~;~~ Figure 32~~graph~~ (a) shows the ~~observed results of~~ tumor volume of each mouse~~;~~ and Figure 32 ~~graph~~ (b) shows ~~the observed results of the~~ survival rate of each mouse group. ~~In~~ In the ~~Fig.~~Figure, "A549" shows ~~mice~~cause with three ~~times~~ administrations of AdE3-1A1.3B infected carrier cell A549 without tumor vaccination ~~and~~, "OVHM-RT→A549" shows ~~mice~~cause with three ~~times~~ administrations of AdE3-1A1.3B infected carrier cells A549 after tumor vaccination with irradiated OVHM. ~~The~~ The number (n) of each mouse group ~~including~~was five animals ~~is shown by n = 5~~.

Best mode for carrying out the present ~~invention~~disclosure

~~[0023]~~ One embodiment ~~of~~to carrying out the present ~~invention~~disclosure ~~is given will be explained~~.

[1] Carrier cells and others used for a cancer gene therapeutic drug of the present ~~invention~~disclosure.

~~At first,~~ The carrier cells used for a cancer gene therapeutic drug of the present ~~invention~~disclosure ~~are described below will be explained~~. The carrier cells can be selected, for example, from the following cells ~~of (1) (4)~~:

(1) A549 cells

(2) 293 cells

(3) SW626 cells

(4) HT-3 cells (HT-III cells).

~~[0024] Fig.~~Figure 1 shows the results of screening ~~of~~ the carrier cells to find ~~out~~ effective carrier cells to use for the cancer gene therapeutic drug. ~~,~~ More specifically, the cancer gene therapeutic drug was prepared by infection of the oncolytic virus to candidate cell lines and the inhibitory effects on the ~~results of investigation of~~ cancer cell proliferation ~~inhibitory effects~~ are shown. Adenovirus AdE3-1A1.3B (IAI.3B) was used as the oncolytic virus. The adenovirus AdE3-1A1.3B has an E1A gene and an E3 gene, and an ovarian cancer specific 1A1.3B promoter (IAI.3B promoter) as a tumor specific promoter ~~at the upper~~ upstream of the E1A gene. ~~,~~ The adenovirus AdE3-1A1.3B was infected to various candidate cell lines at a ~~rate~~concentration of 500 vp/cell for two days and then added to the ovarian cancer cells HEY on culture day two, and the inhibitory effect ~~proliferation inhibitory effect~~ on the proliferation of the cancer cells HEY was investigated on culture day five.

~~[0025]~~ The vertical axis of ~~Fig.~~Figure 1 shows the cell number capable ~~of~~to obtaining 50% inhibitory effect (IC_{50}) on proliferation ~~inhibitory effect (IC_{50}) by the~~for various candidate cell lines. The ~~lowerss~~ the number of cells indicates a ~~shows the~~ higher inhibitory effect on proliferation ~~inhibitory effect~~. As shown in~~by~~ the Figure, the presently investigated cancer cell lines showed a high ~~proliferation~~ inhibitory effect on proliferation in the order of 293 cells, A549 cells, SW626 cells and HT-3 cells (HT- III cells). The 293 cells, A549 cells and SW626 cells exhibited about a 100-fold higher ~~proliferation~~ inhibitory effect on proliferation in comparison to

that in PA-1 cells, which previously have been used as carrier cells. HT-3 cells also showed about a similar high proliferation inhibitory effect on proliferation as with that of SW626 cells.

[0026] In addition, an oncolytic adenovirus was infected into the above mentioned 293 cells, A549 cells, SW626 cells and HT-3 cells to prepare the cancer gene therapeutic drugs, and tTheir inhibitory effect on cancer cell proliferation inhibitory effect was investigated in the presence of a sufficient amount of anti-adenovirus neutralizing antibodies [Ab(+)]. As shown in Fig.Figure 4, all cancer gene therapeutic drugs which used the above mentioned four cell lines as carrier cells showed a potent inhibitory effect cancer cell proliferation inhibitory effect. The conventional cancer gene therapeutic drug with a virus was considered to have a difficult to use withy in frequent administrations because of the production of antibodies. However, the use of the above mentioned four cell lines as carrier cells provided a potent *in vitro* proliferation inhibitory effect on proliferation, despite of the presence of antibodies. In addition, A549 cells used as the carrier cell showed the most potent proliferation inhibitory effect on proliferation among the above mentioned four cell lines as shown in Fig.Figure 4. That is, administration ofering the adenovirus infected A549 cells in the presence of a sufficient amount of the anti-adenovirus neutralizing antibodies almost completely inhibited the proliferation of the target cancer cells, even withunder the presence of the antibodies.

[0027] AIn additionally, *in vivo* experiments using a massive subcutaneous tumor (10 - 15 mm diameter) nude mouse model of 10-15 mm diameter showed potent antitumor effect when the above mentioned A549 cells, 293 cells and SW626 cells were used as the carrier cell (see Fig.Figure 5 and Fig.Figure 6). The details of these experiments will be explained in the examples described later.

[0028] As shown above, the cancer gene therapeutic drug obtained by infection of the oncolytic virus to the carrier cell is capable ofto exhibiting in a high antitumor effect by the use of any one of the carrier cells, A549 cells, 293 cells, SW626 cells and HT-3 cells as the carrier cell.

The [0029] Aabove mentioned four cell lines are explained. A549 cells are derived from a non-small-cell lung cancer cell line, and their details are described, for example, in the article of Giard, D.J., Aaronson, S.A., Todaro, G.J., Arnstein, P., Kersey, J.H., Dosik, H., and Parks, W.P., *In vitro* cultivation of human tumors: establishment of cell lines derived from a series of solid tumors, J. Natl. Cancer Inst., **51**: 1417 - 1423, 1923. The 293 cells are derived

from human embryonic kidney cells and have been used in many experiments and studies as adenovirus producing cells. The 293 cells are explained, for example, in the article of Xie QW, *et al.*, Complementation analysis of mutants of nitric oxide synthase reveals that the active site requires two hemes, Proc. Natl. Acad. Sci., USA, **93**: 4891 - 4896, 1996. The SW626 cells are a metastatic strain of colon cancer in the ovary and their details are described, for example, in the article of Fogh J., *et al.*, Absence of HeLa cell contamination in 169 cell lines derived from human tumors, J. Natl. Cancer Inst., **58**: 209 - 214, 1977. The HT-3 cells are uterine cervix squamous ep. cancer cells and their details are described, for example, in the article of Fogh J., *et al.*, Absence of HeLa cell contamination in 169 cell lines derived from human tumors, J. Natl. Cancer Inst., **58**: 209 - 214, 1977. These four cell lines are available from cell preserving organizations ~~such as~~, such as, ATCC (American Type Culture Collection) and other commercially available cell~~s~~ depositories ~~may be used~~.

[0030] A549 cells have many advantages when used as the carrier cell ~~such as~~, such as, (1) production of a high titer of oncolytic adenovirus and so tough that they can be easily handled, (2) most potent inhibition of proliferation of cancer cells in the presence of anti-adenovirus antibodies, (3) release of secretory granules due to infection of virus, ~~such as~~, such as, adenovirus, because A549 cells are derived from alveolar epithelial cell type II, and the property is favorable in the cancer gene therapy, and (4) resistance to cell elimination effect by CTL even after infection with adenovirus. Therefore, adoption of A549 cells is particularly preferable among the above mentioned four cell lines.

[0031] Multiple kinds of cells may be used as the carrier cells. A combination of A549 cells and 293 cells in the example described later revealed a potent cancer therapeutic effect. Concurrent use of ~~multiple plural~~ kinds of cells may utilize their respective characteristic features and advantages, and ~~it~~ is preferable. For example, SW626 cells require a comparatively long period for adhesion and widely disperse into the surrounding area~~s with by~~ intraperitoneal administration, without restriction in the administered site, and are considered preferable for the intraperitoneal therapy ~~such as~~, such as, ovarian cancer. SW626 cells show the characteristic features of a late peak in their virus productivity than those of A549 cells and 293 cells, resulting in a comparatively longer period of function.

[0032] As described above, adoption of the above mentioned four cell lines (that is, A549 cells, 293 cells, SW626 cells and HT-3 cells) as the carrier cell is preferable. However, cells

~~useable~~utilizable as the carrier cell are not limited to the above mentioned four lines and other cells ~~such as,~~ such as, PA-1 cells (e.g. particularly herpes virus used as an oncolytic virus), fibroblasts, and other human derived cancer cells, normal cells and patient derived cancer cells may be used as the carrier cell.

[0033] In the cancer gene therapeutic drug of the present ~~invention~~disclosure, a conventional virus vector used for gene introduction may be used as an oncolytic virus to infect the carrier cell~~.~~. Adenovirus, adeno-accompanying virus, herpes simplex virus type 1 (HSV-1), herpes simplex virus type 2 (HSV-2), ***Lentivirus*** ~~such as,~~ such as, HIV virus (AIDS virus), retroviruses ~~such as,~~ such as, mouse leukemia virus, reovirus and vesicular stomatitis virus (VSV) can be exemplified and furthermore other oncolytic viruses may be used~~.~~. The oncolytic virus is a proliferative virus vector and any virus that modifies ~~the~~y viral gene so as to specifically proliferate in the target tumor cells or tumor tissues, and fuse or kill target cells with cell lysis (cytolysis) action may be used~~.~~. For example, an adenovirus having an E1A or E1B domain necessary for proliferation may be used.

[0034] The cancer gene therapeutic drug of the present ~~invention~~disclosure can be applied to almost all malignant tumors and may include, for example, ovarian cancer, squamous epithelium cancers (e.g. uterine cervix carcinoma, cutaneous carcinoma, head and neck cancer, esophageal cancer and lung cancer), digestive tract cancers (e.g. colon~~ic~~ cancer, pancreatic cancer, hepatic cancer and gastric cancer), neuroblastoma, cerebral tumor, mammary cancer, testicular cancer and prostatic cancer~~.~~. In addition, adoption of adenoviruses types 34 and 35, which are capable of infection to blood ~~cells~~cells, gives the cancer gene therapeutic drug of the present ~~invention~~disclosure applicable to blood malignant tumors.

[0035] Types of the tumor specific promoter to be introduced into the oncolytic virus may be selected according to the kind of target cancer~~.~~. For example, 1A1.3B promoter for ovarian cancer, midkine promoter for ~~such as,~~ such as, cerebral tumor and malignant glioma, β-HCG promoter for testicular cancer, SCCA1 promoter and SCCA2 promoter for squamous epithelium cancers, CEA promoter for colonic cancer, PSA promoter for prostatic cancer and AFP promoter for hepatic cancer may be used~~.~~. Naturally, other known tumor specific promoters ~~such as,~~ such as, the cox-2 promoter, which has~~ving~~ a wide action spectrum and exhibit~~sing~~ promoter activity to various malignant tumors, and other cancer specific promoters ~~such as,~~ such as, osteocarcine promoter may be used. The Aabove mentioned midkine

promoter may be used ~~on~~to various malignant tumors in addition to cerebral tumor and malignant glioma and has a wide action spectrum, as well as, the ~~-~~cox-2 promoter.

[0036] ~~-~~No specific limit is given for the length of each promoter sequence as far as it exhibits the tumor specific promoter activity~~-~~. The Aabove mentioned 1A1.3B promoter can be designed and prepared according to the disclosures in the pamphlet of International Publication No. 03/025190 and the literature, Cancer Research **63**, 2506~~-~~ - 2512, 2003 and can be inserted in a virus genome~~-~~. The Aabove mentioned ~~midlkine~~ midkine promoter, β-HCG promoter and SCCA1 promoter can be designed and prepared according to the disclosures in the pamphlets of International Publication Nos. 02/10368, 01/90344 and 00/60068, respectively.

The [0037] Aabove mentioned SCCA1 promoter is explained in detail in the article by Katsuyuki Hamada, Hiroto Shinomiya, Yoshihiro Asano, Toshimasa Kihana, Mari Iwamoto, Yasushi Hanakawa, Koji Hashimoto, Susumu Hirose, Satoru Kyo and Masaharu Ito, Molecular cloning of human squamous cell carcinoma antigen 1 gene and characterization of its promoter, Biochimica et Biophysica Acta, 91522 (2001) 1~~-~~ - 8. ~~Molecular cloning of human squamous cell carcinoma antigen 1 gene and characterization of its promoter, Katsuyuki Hamada, Hiroto Shinomiya, Yoshihiro Asano, Toshimasa Kihana, Mari Iwamoto, Yasushi Hanakawa, Koji Hashimoto, Susumu Hirose, Satoru Kyo and Masaharu Ito~~.

[0038] ~~-~~For example, preparation of an oncolytic adenovirus can be accomplished by insertion of a tumor specific promoter ~~at the upper~~ upstream of a primary gene E1A or E1B essential for the proliferation of adenovirus, or replacement with a primary gene E1A or E1B promoter~~-~~. Similar insertion of the tumor specific promoter ~~at the upper~~ upstream of a gene essential for the proliferation of virus is performed when viruses other than adenovirus ~~such as~~, such as, HSV-1, HSV-2, retrovirus, reovirus and vesicular stomatitis virus (VSV) are used for the construction.

[0039] ~~-~~However, it is not necessary for the oncolytic virus to have the tumor specific promoter as far as it has specific proliferative property in the target tumor cells or tumor tissues~~-~~. For example, oncolytic adenoviruses ~~such as~~, such as, an E1B gene deficient type oncolytic adenovirus of ONYX Pharmaceuticals Inc. or an E1A gene partially deficient type Ad5-Δ24 adenovirus of University of Alabama at Birmingham (UAB) may be used~~-~~. Thus, an oncolytic virus~~es~~ deficient of a tumor specific promoter also may be ~~also~~ used~~-~~. Further, a wild type adenovirus or a partially gene deficient type thereof may be used as the oncolytic virus.

[0040] Infection of the oncolytic virus to the carrier cell can be performed by conventional methods without restriction, for example, seeding of carrier cells on a plate, addition of the oncolytic virus at an amount sufficient to infect all cells, cultivation in RPMI medium and fetal calf serum (FCS) (-), under 95% O_2 and 5% CO_2 atmosphere at 37°C for about 6 - 36 hours, which is simple and easily to operateble. In the examples shown later, A549 cells, SW626 cells and HT-3 cells were cultured by this method and infected with the oncolytic virus, whereas 293 cells were cultured in DMEM medium and 10% FCS(+) and infected with the oncolytic virus. Fetal calf serum (FCS) is preferably kept under FCS(-) for 3 - 6 hours infection. Infection for an additional further period is preferably carried out under FCS(-) for 3 - 6 hours and then FCS is added at a concentration of 10%.

[0041] The amount and period of oncolytic virus infection to the carrier cell may be suitably selected according to factors such as, such as, the volume and typekind of tumor to be treated, typekind and rateconcentration of the carrier cell, typekind of used oncolytic virus and administration method of the cancer gene therapeutic drug of the present inventiondisclosure. Examples are, without particular restriction,

for about 6 - 24 hours at about 5 - 250 vp/cell by intraperitoneal administration and for about 12 - 24 hours at about 5 - 500 vp/cell by intratumoral administration with the in use of A549 cells;

for about 6 - 24 hours at about 250 - 2,000 vp/cell by intraperitoneal administration and for about 12 - 24 hours at about 100 - 500 vp/cell by intratumoral administration with thein use of SW626 cells; and

for about 12 - 24 hours at about 5 - 50 vp/cell by intratumoral administration and for about 6 - 24 hours at about 0.1 - 10 vp/cell by intraperitoneal administration with thein use of 293 cells.

As shown above, the amount and period of infection vary according to the typekinds and administration methods of the carrier cells. The above examples set them within about 6 - 24 hours at about 0.1 - 2,000 vp/cell by intraperitoneal administration, and about 12 - 24 hours at about 5 - 500 vp/cell by intratumoral administration.

[0042] The carrier cell may be stored kept without infection of the oncolytic virus, so they are available before use, for the preparation asof virus infected carrier cells after by infection of the oncolytic virus to the carrier cells. Storage of virus infected carrier cells is

also ~~possible~~preferable ~~in a form prepared~~ by freezing the irradiated carrier cells infected with an oncolytic virus, and thawing them at the place of medical treatment~~.~~ The storage of the carrier cells may be, for example, ~~performed~~ in ~~a~~ liquid nitrogen or at about -150℃~~.~~ On the other hand, the oncolytic virus may be kept, for example, at about -80℃.

[0043] Before use, the oncolytic virus is infected to the carrier cell by the aforementioned method and the resultant virus infected carrier cells can be administered "as ~~it~~ is" or together with a conventional pharmaceutical carrier to a human body (or experimental animals ~~such as~~, such as, mouse and rat)~~.~~ As shown later, simultaneous administration ~~of~~ering one or more combinations of atelocollagaen, an iron preparation and a porphyrin compound together with the carrier cell is preferable~~.~~ Administration ~~of~~ering carrier cells infected with an~~not only~~ oncolytic virus and a~~but also~~ GM-CSF expression vector (virus vector double infected carrier cells) is also preferable.

[0044] The carrier cell is administered at a predetermined period after administration ~~of~~ering a virus for immunological treatment~~.~~ When cancer cells are used as the carrier cell, radiation exposure before or after virus infection is preferable~~.~~ Radiation exposure at a dose of 120~~-~~ ~~-~~ 400 Gy, 20~~-~~ ~~-~~ 40 Gy or 20~~-~~ ~~-~~ 40 Gy was performed before the administration ~~of~~ering A459 cells, SW626 cells or HT-3 cells, respectively, as the carrier cell in the examples shown later~~.~~ The dose of radiation exposure to A549 cells was investigated and no cell proliferation was observed at a dose of 120 Gy or over (~~Fig.~~Figure 29) and radiation exposure dose is preferably set between 120 Gy and 600 Gy (more preferably, between 150 Gy and 400 Gy).

[0045] The carrier cell may be preferably administered as a parenteral preparation~~;~~ however, administration as an oral preparation may be also applicable~~.~~ Administration as a parenteral preparation may be performed by an *in vivo* or *ex vivo* method~~.~~ The dosage of *in vivo* administration (in other words, the dosage of virus infected carrier cells) may be adjusted according to the volume and type~~kind~~ of tumor, severity of disease, and patient's age and body weight~~,~~ etc~~.~~ For example, administration may be performed by intracavitary injections ~~such as~~, such as, intravenous injection, intravenous drip infusion, intratumoral injection and intraperitoneal injection~~.~~ Among them, the carrier cell is preferably administered by intratumoral injection~~.~~ These injection preparations may be prepared by conventional procedures and general diluents ~~such as~~, such as, a saline solution and a cell culture solution may be used~~.~~ Furthermore, a bactericide, an antiseptic, a stabilizer, a tonicity agent and an

analgesic may be added if necessary. No particular limit is given for the blending quantity of the virus infected carrier cells in these preparations and can be set to suitable levels.

The above mentioned virus infected carrier cells, of course, may be administered in several divided doses to patients or in several divided courses with optional sets of administration times and intervals.

As shown above, the dosage of virus infected carrier cells can be determined according to the volume and kind of tumor, severity of disease, and patient's age and body weight, etc. Generally, the dosage of carrier cells can be set between about 10^7 cells and 10^{10} cells for one administration, whereas the dosage of oncolytic viruses through the carrier cell can be set between about 10^9 viral particles and 10^{14} viral particles for one administration.

The kind of carrier cell may be suitably selected according to the kind of cancer to be treated. The carrier cell may be modified by a gene recombinant technology, for example, an artificial expression of a specific protein on the surface of the carrier cell to make easy the binding with the target tumor cells, or treatment such as, such as, infection of Sendai virus to the carrier cell.

The oncolytic virus can infect from the carrier cells to the target cells by cell to cell interaction, specifically proliferates in the tumor cells and exerts cell lysis (cytolysis) action of fusion or killing of the tumor cells. The cancer gene therapy with a virus was considered to have a difficulty to use with in frequent administrations because of the production of its antibodies, however, the carrier cells directly establish infection to the target tumor cells by cell to cell interaction, and to make frequent administrations possible and a potent antitumor effect can be expected.

[2] The cancer gene therapeutic drug of the present inventiondisclosure and its preferred application example

The cancer gene therapeutic drug of the present inventiondisclosure is a combination of: a virus for immunological treatment to be administered for inducing a CTL reaction within a living body to the administration of thea carrier cell; and a carrier cell having been infected with an oncolytic virus before the administration so as to make the oncolytic virus act on a tumor cell within the living body. In other words, it is a combination of two drugs; of a virus for immunological treatment administered in advance and then a carrier cell isthen administered.

Administration of ering the virus for immunological treatment such as, such as, adenovirus (immunization in advance) followed by administration of ering the carrier cell infected with the oncolytic virus induces and raises the CTL reaction within the living body and can obtain a very potent *in vivo* antitumor effect.

[0051] The cancer gene therapeutic drug of the present inventiondisclosure showed a dramatic antitumor effect in a practical experiment using a syngenic model mouse with a normal immune system. Although the details will be described later, the ovarian cancer cells OVHM were subcutaneously transplanted to (C57BL/6×C3/He) F1 micecouse who and were locally injected with carrier cells (A549 cells) infected with an oncolytic adenovirus having an ovarian cancer specific promoter. Mice immunized in advance with adenovirus (Ad-β-gal) three months before the injection showed a marked antitumor effect 3 , 4 days after the start of administration, and the tumor hadwas completely disappeared after nine days and lymph node metastasis hadwas also diminished (see Fig.Figure 7 and Fig.Figure 18 and thereafter).

[0052] As mentioned above, more potent and dramatic antitumor effect was obtained in the experiment using the mice with normal immune system, producing antibodies. This result shows that the CTL reaction (cytotoxic activity through cytotoxic T lymphocytes) was induced and raised within the living body, by prior administration of ering the virus for immunological treatment. The conventional cancer gene therapeutic drug with a virus was considered to have a difficulty to use with in frequent administrations because of the production of its antibodies, however, the cancer gene therapeutic drug of the present inventiondisclosure instead rather makes use s of the immune system within the living body and uses it to attack the virus infected target tumor cells.

[0053] The virus for immunological treatment is preferably the same typekind as the oncolytic virus. Non-proliferative type and/or inactivated virus may be preferably used as the virus for immunological treatment. A Nnon-proliferative type virus inactivated by treatment such as, such as, UV irradiation to disrupt the DNA, may be more preferably used. For example, anthe adenovirus with an E1 domain deletion and/or inactivated by UV irradiation to disrupt DNA is favorably used as the virus for immunological treatment. A Pproliferative virus inactivated by UV irradiation, etc., may be used as the virus for immunological treatment.

[0054] In the examples described later, an adenovirus (Ad-β-gal) deficient of E1 domain, having LacZ gene encoding β-galactosidase (β-gal) under the control of cytomegalovirus (CMV)

promoter, was used for the virus ~~of~~for immunological treatment~~.~~. Of course, other viruses can be used ~~as~~for the virus for immunological treatment~~.~~. For example, a proliferative adenovirus inactivated by UV irradiation may be used~~.~~. ~~A N~~non-proliferative adenovirus having polyA sequence without integration of any gene (Ad-polyA), inactivated by UV irradiation, may be preferably used.

[0055] ~~Dosages~~ of the virus for immunological treatment in the cancer gene therapeutic drug of the present ~~invention~~disclosure are suitably selected according to the patient's antibody titer to the~~its~~ virus, volume and type~~kind~~ of tumor, severity of symptoms, and age and body weight of patient~~.~~. Alteration of the dosage in accordance to whether the patient is ~~the antibody~~ positive or negative for the antibodies to the ~~its~~ virus is ~~prefer~~preferredable~~.~~. For example, if adenovirus type 5 is used ~~as~~for the virus for immunological treatment and the oncolytic virus, the concentration~~rate~~ of the virus for immunological treatment may be set between about 10^5 viral particles and 10^{11} viral particles for patients who are~~with~~ antibody negative (-), and may be set between about 10^2 viral particles and 10^7 viral particles for patients who are with antibody positive (+). The ~~Administration~~ method of administering the virus for immunological treatment is not restricted, although intracutaneous or subcutaneous injection is ~~prefer~~preferredable.

[0056] ~~In~~ addition, the dose of each drug for~~to~~ animals ~~such as~~, such as, mice~~ouse~~ and rats may be set at about 1/1,000 to that for a human body in consideration of the differences in body weight, for experimental administration ofering the cancer gene therapeutic drug of the present ~~invention~~disclosure.

[0057] ~~The~~ interval between ~~of~~ administration ofering the virus for immunological treatment and administering ~~that of~~ the carrier cell may be set between about two weeks and three months~~.~~. The shorter period is more preferable~~.~~. In the examples described later, inactivation of the virus for immunological treatment (adenovirus) by UV irradiation shortened the above mentioned interval to about three weeks or four weeks.

[0058] ~~Dosages~~ of virus infected carrier cells are as mentioned before and one dose of the oncolytic virus through the carrier cell may be set between about 10^9 viral particles and 10^{14} viral particles, and the infection ~~rate~~concentration of the oncolytic virus to the carrier cell may be set between about 0.1 vp/cell and 2,000 vp/cell. ~~(~~Preferably between 5 vp/cell and 500 vp/cell. ~~:~~ More preferably between 150 vp/cell and 400 vp/cell~~)~~.

[0059] For tumor vaccination, administration ofering tumor cells (cancer cells) together with, before or after, the administration ofering the virus for immunological treatment is preferable. That is, vaccination with the tumor cells (to enhance the immunological response in aof living body to the target tumor cells by the administration ofering the tumor cells treated in advance with radiation exposure, ethanol or formaldehyde) is preferable together with, before or after immunization by the virus for immunological treatment.

[0060] Tumor cell derived from a patient is preferpreferredable for the tumor cells used for the above tumor vaccination (tumor immunization), and commonly available tumor cells with similar antigen may be used. The examples described later investigating the therapeutic effect to ovarian cancer (by OVHM) showed a favorable therapeutic effect by usinge aof cancer cells (squamous epithelial cancer cells SCC7 and lung cancer cells A549), for tumor vaccination that is, different from the target cancer cell to be treated.

[0061] In the above tumor vaccination (tumor immunization), no particular limited concentrationrate of tumor cell is given. For example, it may be set between about 10^5 cells and 10^{10} cells. The radiation exposure dose to the tumor cells is preferably set between 120 Gy and 600 Gy. (mMore preferably between 200 Gy and 500 Gy). The Preferabe preferred administration method is intracutaneous injection or subcutaneous injection.

[0062] Furthermore, administration ofering an iron preparation and/or a porphyrin compound may be used to enhance the viral productivity in the cancer to be treated. Porphyrin compounds such as, such as, 5-aminolevulinic acid (ALA), hematoporphyrin and photofirin are exemplified. As iron preparations, ferrous sulfate ($FeSO_4$) and ferrous citrate for oral administration, and chondroitin sulfate iron and sugar containing iron oxides for intravenous administration may be exemplified. The Aadministration method is not limited, although an injection preparation or oral preparation is preferable, together with the cancer gene therapeutic drug of the present inventiondisclosure.

[0063] Practically, administration ofering an iron (Fe) preparation and/or 5-aminolevulinic acid (ALA) could markedly enhance the inhibitory effect of the oncolytic adenovirus AdE3-1A1.3B on cancer cell proliferation (see Fig.Figures 15 - 17 and Fig.Figure 28).

[0064] Administration ofering atelocollagen (product prepared by cleavage of only telopeptide bond of collagen by pepsin treatment, etc., making the molecular weight small and

water soluble) together with the carrier cell is also ~~prefer~~preferredable. As shown in examples described later, ~~simultaneous administration of~~ering atelocollagen and the carrier cell simultaneously, dramatically reduced the death rate caused by side effects (~~Fig.~~Figure 24). This might be caused by inhibition of dispersion of the oncolytic adenovirus and a block against anti-adenovirus antibodies that was produced by the atelocollagen.

[0065] Therefore, ~~simultaneous administration of~~ering atelocollagen and the carrier cell simultaneously can suppress side effects and realize a high dose administration of the oncolytic virus. Commercially available atelocollagen (e.g. a product of Koken Co., Ltd.) or a product prepared by treatment of collagen with pepsin may be used. Atelocollagen is preferably administered by mixing it with the~~an~~ injection solution together with the carrier cells. ~~A C~~concentration of~~at~~ 0.01 3.0% (w/v) in the solution is considered to exhibit a sufficient effect. (Examples described later showed a sufficient effect at a low concentration of 0.1 0.2% (w/v) in the solution).

[0066] Furthermore, as described earlier, administration of~~ering~~ the carrier cells doubly infected with an ~~not only~~ oncolytic virus vector and a ~~but also~~ GM-CSF expression virus vector is preferred to enhance the immune response ~~is preferable.~~ (Or, it is possible to simultaneously administration of~~r~~ two kinds of carrier cells each infected with one of the above virus vectors ~~may be adopted~~.)

It is preferred that [0067] T~~t~~he GM-CSF expression vector is ~~preferable~~ the same kind of virus vector as the oncolytic virus. For example, when adenovirus is used as the oncolytic virus, one may use, for the GM-CSF expression vector, an adenovirus deficient of E1 domain and ~~with~~ a GM-CSF gene encoding granulocyte-macrophage colony stimulating factor (GM-CSF).

[0068] U~~In using~~ of the GM-CSF expression vector, as well as, the oncolytic virus, a total concentration~~rate of infection~~ of both virus vectors to the carrier cell may be set between 5 ~~five viral particles~~vp/cell and 2,000 ~~viral particles~~vp/cell.

[0069] Application of the GM-CSF expression vector showed a ~~very~~highly excellent cancer therapeutic effect (~~Fig.~~Figure 27).

[0070] Instead of the GM-CSF expression vector, GM-CSF protein may be mixed in an injection solution together with the carrier cells, or the protein's administration by intravenous administration may be taken in consideration.

[0071] Methods for use of the cancer gene therapeutic drug of the present ~~invention~~disclosure are, of course, not restricted to the methods described above and various methods for use are available. For example, the cancer gene therapeutic drug of the present ~~invention~~disclosure may be concurrently used with other anticancer agents or a radiation therapy to enhance the infectivity of the oncolytic virus.

Examples of the [0072] ~~A~~ preferred ~~example for~~ use of the cancer gene therapeutic drug of the present ~~invention~~disclosure will be ~~given~~explained by dividing them into (1) patients that are negative for the ~~with~~ antibod~~ies~~y ~~negative~~ to the virus for immunological treatment and (2) patients that are positive for the ~~with~~ antibod~~ies~~y ~~positive~~ to the virus for immunological treatment.

[0073] In the above case (1), non-proliferative adenovirus inactivated by UV irradiation, as described earlier, may be used for the virus for immunological treatment. The amount is about 10^5 vp to 10^{11} vp. Patient's derived tumor cells (cancer cells) irradiated at about 200 Gy for tumor vaccination may be administered at 10^5 cells to 10^{10} cells together with the virus for immunological treatment. The virus for immunological treatment and the tumor cell may be administered by intracutaneous or subcutaneous injection.

[0074] About 3 - 4 weeks after administering ~~rations of~~ the virus for immunological treatment and the tumor cell, the carrier cell may be administered by intratumoral administration. The dose of the carrier cells may be set about 1×10^7 to 1×10^{10} cells for one administration. A549 cells, irradiated at about 150 Gy to 400 Gy and then administered, may be used as the carrier cell. The adenovirus may be used for the oncolytic virus and the GM-CSF expression vector, and may be infected to the carrier cell at about 250 vp/cell and 5 - 20 vp/cell, respectively. Atelocollagen may be mixed with an injection solution at a concentration of about 0.1 - 0.2% and then administered. Simultaneously, an iron (Fe) preparation may be intravenously administered at a dose about 40 - 100 mg. ALA may be simultaneously administered into the tumor at a dose of 2 - 2,000 mg.

As mentioned above, the carrier cells, etc. may be administered ~~once~~at one time. However, ~~T~~the carrier cells, etc., may be administered 1 - 6 times ~~administered~~. Administering ~~ration in plural~~multiple times may be carried out in consecutive days or at intervals of 2 - 3 days.

[0075] In the above case (2), ~~of~~ patients with positive antibodies, the cancer gene

therapeutic drug of the present ~~invention~~disclosure may be administered in a similar manner with that of the above-mentioned case (1), except for setting the ~~amont~~ amount of the virus for immunological treatment at about 10^5 vp or less.

[0076] Practical examples of the cancer gene therapeutic drug of the present ~~invention~~disclosure are ~~such as~~, such as,

(1) a combination of the virus for immunological treatment and the carrier cell,

(2) a combination of the virus for immunological treatment, the carrier cell and the oncolytic virus for the infection to the carrier cell,

(3) a combination with atelocollagen added to the above combinations (1) or (2),

(4) a combination with GM-CSF expression vector added to the above combinations (1)-(3),

(5) a combination with an iron preparation and/or a porphyrin compound added to the above combinations (1)-(4) to enhance the viral productivity,

(6) a combination with the tumor cell for tumor vaccination added to the above combinations (1)-(5), and

(7) a combination with the necessary compounds for storage, infection and culture, and preparation of medical preparations (e.g. a reagent, a buffer and an enzyme), or vessels (e.g. for reaction, infection and culture, and storage) added to the above combinations (1)-(6).

Examples

[0077] Examples of the present ~~invention~~disclosure are explained referring the drawings, however, the scope of the present ~~invention~~disclosure is not restricted by these examples.

[0078] [Example 1: Screening of the carrier cell and antitumor effect in the presence of antibodies]

The following experiments were carried out to screen cancer cell lines which exhibit a potent inhibitory effect on cancer cell proliferation when they are used ~~inhibitory effect~~ as the carrier cell.

[0079] Adenovirus AdE3-1A1.3B (IAI.3B) was used as the oncolytic virus for the infection to the carrier cell. The adenovirus AdE3-1A1.3B has an E1A gene and an E3 gene,

and an ovarian cancer specific 1A1.3B promoter (IAI.3B promoter) as a tumor specific promoter ~~at the upper~~ upstream of the E1A gene~~.~~. The adenovirus AdE3-1A1.3B was infected to various carrier cells at a ~~rate~~concentration of 500 vp/cell for two days, and then the carrier cells were added to an ovarian cancer cell line HEY on culture day two and their *in vitro* inhibitory effects on proliferation ~~inhibitory effects~~ were investigated on culture day five.

[0080] The results of the above experiment are shown in ~~Fig.~~Figure 1~~.~~. The vertical axis of the graph shows cell numbers capable to obtain a 50% inhibitory effect (IC_{50}) on proliferation ~~inhibitory effect (IC_{50})~~ for each cell line, and a ~~the~~ low ~~ese~~ cell number shows a ~~the~~ higher ~~proliferation inhibitory effect~~inhibitory effect on proliferation~~.~~. As shown in the Figure, the cancer cell lines investigated in the present experiment showed high antitumor effects in the~~an~~ order of 293 cells, A549 cells, SW626 cells and HT-3 (HT-III) cells~~.~~. The 293 cells, A549 cells and SW626 cells exhibited about a 100-fold higher ~~proliferation~~ inhibitory effects on proliferation in comparison to PA-1 cells which previously have been used as the carrier cells~~.~~. HT-3 cells also exhibited a similar high ~~proliferation inhibitory effect~~inhibitory effect on proliferation as~~to~~ that of SW626 cells.

[0081] Then, the difference in the inhibitory effect on proliferation, in the presence of antiviral antibodies, was it was examined ~~how was difference in the proliferation inhibitory effect~~ between using only the oncolytic virus, and a combination of the oncolytic virus and the carrier cell~~, in the presence of antiviral antibodies.~~. As the carrier cell, a 293 cell was used and the above mentioned adenovirus AdE3-1A1.3B was infected for two days~~.~~. The resultant adenovirus AdE3-1A1.3B infected 293 cells and ~~their~~ supernatant (AdE3-1A1.3B 293 cell+SUPT) were placed in a 12-well plate in the presence of the anti-adenovirus antibodies~~.~~. In each well, about 50,000 cells of the ovarian cancer cell line HEY had been cultured from the preceding day~~.~~. The anti-adenovirus antibodies were prepared by dilution of the antibodies with 600-fold antibody titer to various antibody titers~~.~~. In the case of only the oncolytic virus, the adenovirus AdE3-1A1.3B was administered in the 12-well plate at a ~~rate~~concentration of 1,000 vp/cell, in the presence of the anti-adenovirus antibodies~~.~~. At culture day five, the respective inhibitory effect on the proliferation of ~~inhibitory effects on~~ cancer cells (HEY cells) were investigated.

[0082] The results of the above experiment are shown in ~~Fig.~~Figure 2~~.~~. The vertical axis of the graph shows the dilution rate of the anti-adenovirus antibodies at 50% ~~proliferation~~

inhibitory effect (IC_{50}) on proliferation. In other words, a 50% ~~proliferation inhibitory effect~~inhibitory effect on proliferation was obtained with~~for~~ 293 cells even at about 5-fold dilution rate (120-fold antibody titer), whereas a 50% ~~proliferation inhibitory effect~~inhibitory effect on proliferation was obtained with~~for~~ only the adenovirus at about 600-fold dilution rate (1-fold antibody titer)~~.~~. As shown above, the carrier cell exhibited an~~the proliferation inhibitory effect~~inhibitory effect on proliferation even under the condition of a high antibody titer.

[0083] Similarly, the ~~proliferation inhibitory effect~~inhibitory effect on proliferation of~~to~~ HEY cells was investigated in the presence of anti-adenovirus antibodies in the following conditions,

(1) adenovirus infected 293 cell and its supernatant (AdE3-1A13B 293 cell+SUPT),

(2) a cell supernatant containing adenovirus (AdE3-1A13B, SUPT),

(3) a filtered~~-one with a filter of~~ [0.2 μm] ~~of the~~ cell supernatant containing adenovirus (AdE3-1A13B, SUPT, filter), and

(4) ~~only~~ only the adenovirus (AdE3-1A13B).

The results are shown in ~~Fig.~~Figure 3~~.~~. The vertical axis of the graph shows a dilution rate of the anti-adenovirus antibodies at a 50% proliferation inhibitory rate (IC_{50})~~.~~. As shown in the ~~Fig.~~Figure, a more potent antitumor effect was obtained in comparison to the other conditions when the carrier cell (293 cell) was used.

~~The [0084] About carrier cells of 293 cells, A549 cells, SW626 cells and HT-3 cells, each proliferation inhibitory effect~~inhibitory effect on the proliferation of~~n~~ the cancer cells HEY was investigated in the carrier cells 293 cells, A549 cells, SW626 cells and HT-3 cells; in either the presence [Ab(+)] or absence [Ab(-)] of the anti-adenovirus antibodies having a 600-fold antibody titer~~.~~. The results are shown in ~~Fig.~~Figure 4~~.~~. The vertical axis of the graph shows the number of ~~the~~ cancer cells on culture day five~~.~~. As shown in the Figure, the most potent ~~proliferation inhibitory effect~~inhibitory effect on proliferation was obtained when A549 cells were used as the carrier cells in four ~~type~~kinds of cells~~.~~. That is, administration of~~ering~~ adenovirus infected A549 cells in the presence of a sufficient amount of anti-adenovirus neutralizing antibodies almost completely inhibited the proliferation of the target cancer cells despite of the presence of the antibodies~~.~~. The ~~O~~other three ~~type~~kinds of cells also showed sufficient ~~proliferation inhibitory effect~~inhibitory effect on proliferation in the presence of the

antibodies.

[0085] The cancer gene therapy with a virus was considered to be have a difficult with multiple y in frequent administrations because of the production of neutralizing antibodies to the virus. However, application of the carrier cell established direct infection to the target cancer cells by cell to cell interaction and frequent multiple administrations became possibleavailable. Furthermore, application of the above mentioned four typekinds of cells as the carrier cell provided potent antitumor effect.

[0086] [Example 2: *In vivo* antitumor effect in a nude mouse subcutaneous tumor model]

Then, *in vivo* antitumor effect of each carrier cell infected with the above mentioned adenovirus AdE3-1A1.3B was investigated using a nude mouse subcutaneous tumor model. In the experiment, human ovarian cancer cells RMG-1 were subcutaneously transplanted into 5-week-old nude mouse. After four weeks, each carrier cell was injected six times into a massive tumor of about 10 - 15 mm diameter and the change inof the tumor volume was observed. The results are graphically shown in Fig.Figure 5. In the graph, the black squares showrepresents the "control" which are the results of six times injectingon of PBS buffer six times into the tumor; the black circlesround showrepresents "AdE3-1A1.3B" which are the results of administration ofering 1×10^{10} viral particles of the adenovirus AdE3-1A1.3B per mouse of the adenovirus AdE3-1A1.3B; the black triangles shows the results of administration ofering 1×10^{7} SW626 cells infected with the adenovirus AdE3-1A1.3B at 250 vp/cell per mouse, infected with the adenovirus AdE3-1A1.3B at 250 vp/cell; the; bBlack diamondsrhombus shows the results of administration ofering 1×10^{7} 293 cells infected with the adenovirus AdE3-1A1.3B at 25 vp/cell per mouse, infected with the adenovirus AdE3-1A1.3B at 25 vp/cell; and, the wWhite squares shows the results of administration ofering 1×10^{7} A549 cells infected with the adenovirus AdE3-1A1.3B at 50 vp/cell per mouse, infected with the adenovirus AdE3-1A1.3B at 50 vp/cell. As shown in the Figure, when 293 cells and A549 cells were used as the carrier cells, they showed complete disappearance of the massive tumor with about {10 - 15 mm diameter} 50 days after the treatmentadministration. SW626 cells showed a 98% proliferation inhibitory effectinhibitory effect on proliferation.

[0087] A similar experiment as shown above was carried out by subcutaneous transplantation of human ovarian cancer cells PA-1 into 5-week-old nude mouse. The results

are shown in ~~Fig.~~Figure 6. As shown in the ~~Fig.~~Figure, the massive tumor ~~with about~~ (10 - 15 mm diameter) completely disappeared by ~~the usinge of~~ 293 cells and A549 cells as the carrier cells. SW626 cells showed complete disappearance of the tumor in four out of five mice.

~~[0088]~~ [Example 3: *In vivo* antitumor effect in subcutaneous tumor model mouse with normal immune system]

The~~n~~ *in vivo* antitumor effect of the cancer gene therapeutic drug of the present ~~invention~~disclosure was investigated using (C57BL/6×C3/He) F1 mice~~ouse~~ with a normal immune function. In the experiment, each antitumor effect was investigated ~~with~~in the following conditions.

(1) T~~t~~he ovarian cancer cells OVHM were subcutaneously transplanted to the syngenic model mouse. After 10 days or more, A549 cells were infected with the adenovirus AdE3-1.3B at a concentration~~rate~~ of 250 vp/cell, followed by radiation exposure, were ~~six times~~ administered six times into a formed 5 - 10 mm tumor.

(2) A~~a~~ 7-week-old syngenic model mouse was immunized in advance with an adenovirus for immunological treatment. After three months, the ovarian cancer cells OVHM were subcutaneously transplanted in a similar manner with that of (1) and then, after 10 days or more, A549 cells infected with the adenovirus AdE3-1A1.3B at a concentration~~rate~~ of 250 vp/cell, followed by radiation exposure, were ~~six times~~ administered six times into a tumor. ~~and~~

(3) PBS buffer ~~was six times~~ administered~~rations of PBS buffer~~ six times into a tumor as a control.

~~[0089]~~ The results of the above experiment are shown in ~~a graph of Fig.~~Figure 7. In the graph, the black squares show the~~represents~~ "control" which are the results of the above condition (3); the black circles~~round represents~~ show "AD(-)→A549" which are the results of the above condition (1), without administration ~~of~~ering the adenovirus for immunological treatment; and the ~~B~~black triangles show ~~represents~~ "Ad(+)→A549" which are the results of the above condition (2), with administration ~~of~~ering the adenovirus for immunological treatment.

A ~~N~~non-proliferative type adenovirus having no E1 gene was used for the adenovirus for immunological treatment. More specifically, it was an adenovirus with an inserted LacZ gene ~~in the~~ downstream of the CMV promoter. As shown by the ~~Fig.~~Figure, the above condition (1), without prior immunization by adenovirus, showed 20% antitumor effect in comparison to

the control, while the above condition (2), with prior immunization by adenovirus, showed a marked antitumor effect 3- - 4 days after the start of administration and the tumor was completely diminished after nine days with a disappearance of lymph node metastasis. As shown by the example, the potent and dramatic antitumor effect in mice with a normal immune system, despite of their antibody production, might be caused by the induction and raising of the CTL reaction within the living body due to the administration of the adenovirus for immunological treatment.

[0090] The oncolytic adenovirus is infected from the carrier cells to the target tumor cells by cell to cell interaction, specifically it proliferates in the tumor cells and is considered to exert cell lysis (cytolysis) action to fuse and/or kill the target tumor cells. The cancer gene therapeutic drug of the present inventiondisclosure is considered to induce a potent CTL reaction within the living body by prior administration of the adenovirus for immunological treatment, which eliminates the oncolytic adenovirus infected target tumor cells and induces complete natural elimination of the adenovirus infected tumor cells.

[0091] One manner of infection of the adenovirus to the target tumor cell is consideredbelieved to be a cell fusion caused by the adenovirus. Fig. Figure 8 is a shows the result of microphotomicrographscopic observation of cells after overnight culture, afterfrom beingthe administration of 10,000 vp/cellviral particles per cell of the adenovirus inactivated by UV irradiation were placed into a well with A549 cells cultured. As shown by the arrow marks in the Fig. Figure, administration of the adenovirus caused cell fusion and multinucleated cells were sporadically observed. No such cells were observed infor A549 cells without administering the adenovirus administration (see Fig. Figure 9).

[0092] Predicted infection manners, other than cell fusion, are a cell adhesion to the target cells by theof carrier cells, and infection of the adenovirus to the target tumor cells by a local burst with a and the carrier cell fragment including the adenovirus. In any way, proliferation of an adenovirus having a tumor specific promoter in the adenovirus infected target tumor cells may lead to presentation of a potent antigen (or, a cancer specific peptide recognized as an antigen secondarily), and the tumor cells may be eliminated by the CTL reaction.

[0093] [Example 4: Antitumor effect by the use of a midkine promoter]

Thean antitumor effect of by the usinge of a midkine promoter was investigated.

~~Fig.~~Figure 10 (a) shows the ~~results of investigation of~~ midkine (MK) mRNA expressions in human surgical samples 1-~~-~~21 by RT-PCR~~.~~ As shown by the ~~Fig.~~Figure, excessive expression of the midkine mRNA was observed in malignant gliomas ~~such as,~~ such as glioblastoma and anaplastic astrocytoma, and in diffuse astrocytoma~~.~~ Thus, the excessive expression of midkine is observed in many cancers ~~such as,~~ such as cerebral tumor~~s~~.

~~[0094]~~ ~~Fig.~~Figure 10 (b) shows the ~~results of investigation of~~ midkine mRNA expression by RT-PCR in four cell lines of malignant gliomas in a similar manner as shown above~~.~~ As shown by the ~~Fig.~~Figure, no expression was observed in U87MG and excessive expression of the midkine mRNA w~~as~~ere observed in U251MG, LN319 and U373MG.

~~[0095]~~ ~~Fig.~~Figure 10 (c) shows the ~~results of investigation of~~ midkine protein expression in the above mentioned each cell line by Western blot~~ting~~ analysis~~.~~ No expression was found in U87MG, as well as, mRNA~~.~~ Excessive expression of the midkine protein was observed in U251MG, LN319 and U373MG.

~~[0096]~~ Then, a promoter assay of the midkine was performed~~.~~ In the experiment, activity of two different length midkine promoters (600 bases and 2,300 bases) was compared~~.~~ Plasmids (pGL3-MK600 and pGL3-MK2300) with ~~inserted~~ a luciferase gene inserted ~~at the~~ downstream of the respective promoters were introduced to each of the above mentioned cell line~~s~~ and their respective luciferase activity was investigated to evaluate the promoter activity~~.~~ The results shown in ~~Fig.~~Figure 11 revealed a higher promoter activity in the 600 base sequence length than ~~that~~ in the 2,300 base sequence length in the malignant glioma cell line.

~~[0097]~~ ~~Fig.~~Figure 12 (a) shows a schematic diagram of the oncolytic (cytolysis type) adenovirus structure having a midkine promoter designed in the present experiment~~.~~ The midkine promoter having a 600 base sequence or a 2,300 base sequence was introduced at the site of 552 bp.

~~[0098]~~ ~~Fig.~~Figure 12 (b) shows the ~~results of investigation of~~ E1A protein expression in the above mentioned each cell line infected with three types of adenoviruses by Western blot~~ting~~ analysis~~.~~ As shown in the Figure, expression of E1A protein of the adenovirus was observed in midkine expressing U251MG, LN319 and U373, by the infection of adenovirus (AdMK600) having a 600 base length midkine promoter~~.~~ Expression of E1A protein was observed in all cells, including normal brain cells, by wild type adenovirus (AdWild) and no expression of the E1A protein was observed in all cells with the~~by~~ control virus AdLacZ.

[0099] ~~Fig.~~Figure 13 (a) shows the results of a comparative investigation of the inhibitory effect on the ~~f~~proliferation of cancer cells ~~proliferation inhibitory effect~~ by three ~~type~~kinds of adenoviruses. ~~,~~ Wild type adenovirus (AdWild) showed a potent ~~proliferation inhibitory effect~~inhibitory effect on proliferation in all cells, whereas adenoviruses (AdMK600 and AdMK2300) having the midkine promoter showed the ~~proliferation inhibitory effect~~inhibitory effect on proliferation only in midkine expressing U251MG, LN319 and U373MG. ~~,~~ These results were well correlated with the results of midkine mRNA expression and promoter activity. ~~,~~ The adenovirus AdMK600 showed a more potent ~~proliferation inhibitory effect~~inhibitory effect on proliferation than ~~that of~~ AdMK2300 which has ~~having~~ a 2,300 base sequence length.

[0100] ~~Fig.~~Figure 13 (b) shows the ~~results of investigation of~~ adenovirus E3 domain's influence on the ~~proliferation inhibitory effect~~inhibitory effect on proliferation. ~~,~~ As shown in the Figure, AdMK600 having an E3 domain exhibited about a 10-fold potent ~~proliferation inhibitory effect~~inhibitory effect on proliferation than an ~~that of~~ adenovirus having no E3 domain (AdMK600-ΔE3).

[0101] ~~Fig.~~Figure 13 (c) shows the ~~results of investigation of~~ antitumor effect of an adenovirus in a nude mouse subcutaneous transplantation model ~~with~~of about a 5 ~~-~~ 100 mm diameter tumor. ~~,~~ In the ~~Fig.~~Figure, the black ~~diamonds~~rhombus marks ~~show represent~~ the results of ~~administration of~~ering the wild type adenovirus AdWild; ~~,~~ the black squares ~~show marks represent~~ the results of ~~administration of~~ering the adenovirus AdMK600 having a midkine promoter; ~~,~~ the black ~~triangles show marks represent the~~ the results of ~~administration of~~ering the adenovirus Ad-β-gal with an inserted LacZ gene; ~~,~~ and the black ~~circles~~round marks ~~represent~~ show the results of ~~administration of~~ering only PBS buffer. ~~,~~ As shown in the Figure, only the wild type adenovirus showed antitumor effect in the U87MG without midkine expression. ~~,~~ In the U373MG expressing midkine, AdMK600, as well as, AdWild produced ~~gave~~ a complete disappearance of tumor. ~~,~~ No marked difference was observed between the control of ~~with~~ injection ~~sed with~~ only PBS buffer and ~~that with~~ injections ~~with~~ed AdLacZ.

[0102] Furthermore, an adenovirus having the above mentioned midkine promoter (Ad-MK600) was infected into the carrier cells and the antitumor effect of the virus infected carrier cells was compared to ~~that of~~ ~~administration of~~ering only Ad-MK600. ~~,~~ In the experiment, 293 cells and A549 cells were used as the carrier cells. ~~,~~ The Aabove mentioned U373MG cells were transplanted into ~~,~~ 5-week-old nude mice ~~use~~ to give a 10 ~~-~~ 15 mm

massive tumor after three weeks. The virus infected carrier cells or only Ad-MK600 were administered and the tumor volume was compared after four weeks. The results are shown in Fig. Figure 14. In the Fig. Figure, "Ad-MK600" shows the results of administration of only Ad-MK600, and each "293" and "A549" show the results of administration of the virus infected carrier cells using 293 cells and A549 cells as the carrier cells, respectively. As shown in the Figure, administration of the virus infected carrier cells showed complete disappearance of the tumor. Administration of only Ad-MK600 showed almost no difference with that of the control.

[0103] Practically, favorable therapeutic effects on the ovarian cancer and malignant glioma were observed by application of carrier cells such as, such as, A549 cells and 293 cells and an adenovirus having a 1A1.3B promoter or midkine promoter as the oncolytic virus. The midkine promoter can be used for various malignant tumors in addition to malignant glioma and is considered effective in the cancer therapy of other than malignant glioma.

[0104] [Example 5: Influences of Fe and ALA on the proliferation inhibitory effect inhibitory effect on proliferation of adenovirus AdE3-1A1.3B]

Ovarian cancer cells HEY were cultured in a 12-well plate at a rate concentration of 10,000 cells/well and $FeSO_4$ was added at a concentration of 50 μg/ml, 5 μg/ml, 0.5 μg/ml or 0 μg/ml on the following day and the cytolysis type adenovirus AdE3-1A1.3B was added to all wells. The proliferation inhibitory effect inhibitory effect on proliferation of the adenovirus was evaluated by IC_{50} after five days. The results are shown in Fig. Figure 15. In the Fig. Figure, the vertical axis shows the relative concentration rate (vp/cell) of viruses at IC_{50} in each condition. As shown in the Figure, administration of ering 50 μg/ml of $FeSO_4$ and the adenovirus showed about 20-fold, and administration of ering 5 μg/ml of $FeSO_4$ and the adenovirus showed about an 8-fold proliferation inhibitory effect inhibitory effect on proliferation, respectively, to that of only adenovirus administration.

[0105] Next, the ovarian cancer cell line HEY was cultured in a 12-well plate at a rate concentration of 10,000 cells/well and 5-aminolevulinic acid (ALA) was added at a concentration of 50 μg/ml, 5 μg/ml, 0.5 μg/ml or 0 μg/ml on the following day and the cytolysis type adenovirus AdE3-1A1.3B was added to all wells. The proliferation inhibitory effect inhibitory effect on proliferation of the adenovirus was evaluated by IC_{50} after five days.

The results are shown in ~~Fig.~~Figure 16~~.~~. In the ~~Fig.~~Figure, the vertical axis shows relative ~~rate~~concentration (vp/cell) of viruses at IC_{50} in each condition~~.~~. As shown in the ~~Fig.~~Figure, administration ~~of~~ering 50 μg/ml of ALA and the adenovirus showed about a 100-fold ~~proliferation inhibitory effect~~inhibitory effect on proliferation to that of only adenovirus administration.

[0106] Furthermore, the ovarian cancer cell line HEY was cultured in a 12-well plate at a ~~rate~~concentration of 10,000 cells/well and $FeSO_4$ was added at a concentration of 50μg/ml, 5μg/ml, 0.5μg/ml or 0μg/ml on the following day~~.~~. ~~An a~~Additionally, the cytolysis type adenovirus AdE3-1A1.3B and 50μg/ml of 5-aminolevulinic acid (ALA) were added to each well~~.~~. Only the adenovirus was added to the~~a~~ control~~.~~. The ~~proliferation inhibitory effect~~inhibitory effect on proliferation of the adenovirus was evaluated by IC_{50} after five days~~.~~. The results are shown in ~~Fig.~~Figure 17~~.~~. In the Figure, the vertical axis shows the relative administration ~~rate~~concentration (vp/cell) of viruses at IC_{50} in each condition~~.~~. As shown in the ~~Fig.~~Figure, concurrent administration of 50_μg/ml of $FeSO_4$, 50_μg/ml of ALA and the adenovirus showed about a 1,000-fold ~~proliferation inhibitory effect~~inhibitory effect on proliferation to that of only adenovirus administration. Concurrent administration of 5_μg/ml of $FeSO_4$, 50_μg/ml of ALA and the adenovirus showed about a 700-fold ~~proliferation inhibitory effect~~inhibitory effect on proliferation to that of only adenovirus administration, and concurrent administration of 0.5_μg/ml of $FeSO_4$, 50_μg/ml of ALA and the adenovirus showed about a 200-fold ~~proliferation inhibitory effect~~inhibitory effect on proliferation to that of only adenovirus administration.

[0107] As mentioned above, it was found that ALA and Fe markedly enhance the ~~proliferation inhibitory effect~~inhibitory effect on proliferation of the oncolytic adenovirus AdE3-1A1.3B. ~~–~~ALA and Fe elevate the infectivity of adenovirus and the amount of virus production, because the β-gal assay revealed increased infectivity of adenovirus and the PFU assay revealed an increased amount of adenovirus production~~.~~. That is, ALA and Fe can enhance the antitumor effect, because they can increase the infectivity of the adenovirus to cancer cells and the amount of virus production within the cells.

[0108] ALA is known to be a porphyrin metabolite taken up into cancer cells and its metabolite protoporphyrin IX is likely to be accumulated by the porphyrin metabolism~~.~~. This compound has photo-sensitizing effect and it can be utilized for the photodynamic therapy (PDT)

of superficial cancer, together with an excimer dye laser.

The [0109] Aabove mentioned protoporphyrin IX binds with Fe to give a heme and forms heme proteins ~~such as~~, such as, cytochrome in cells~~.~~. The heme proteins are involved in the respiratory system in intracellular mitochondria, ATP production and protein synthesis~~.~~. Thus, the heme proteins are involved in protein synthesis, including production of the adenovirus if the adenovirus infected~~.~~. Therefore, promotion of the porphyrin metabolism may lead to the increased adenovirus production.

[0110] The cancer gene therapeutic drug of the present ~~invention~~disclosure, as well as the cancer gene therapy of the present ~~invention~~disclosure, can further increase the therapeutic effect by concurrent use of Fe and/or porphyrin compounds ~~such as~~, such as, ALA~~.~~. That is, concurrent use of Fe and/or porphyrin compounds ~~such as~~, such as, ALA enhances antitumor effect, even under an infection suppressive condition in the presence of antibodies~~.~~ by acceleration of the CTL response caused by the increased adenovirus production in the target cells~~.~~. Concurrent use of Fe and/or porphyrin compounds can enhance the antitumor effect not only in a syngenic mouse model with immune system but also in a human body.

[0111] In the cancer gene therapy using the oncolytic virus, concurrent use of Fe and/or porphyrin compounds ~~such as~~, such as, ALA is expected to enhance the therapeutic effect, even if the carrier cells are not used.

[0112] [Example 6: Investigation for optimization of cancer therapy using the cancer gene therapeutic drug of the present ~~invention~~disclosure]

The following a series of experiments were~~as~~ carried out to optimize the cancer therapy using the cancer gene therapeutic drug of the present ~~invention~~disclosure.

[0113] At first, an investigation of the *in vivo* antitumor effect of the cancer gene therapeutic drug of the present ~~invention~~disclosure was performed in a similar manner to the experiment shown in ~~Fig.~~Figure 7 using a subcutaneous tumor model mouse [(C57BL/6×C3/He) F1 ~~mouse~~mice] with a normal immune system~~.~~. In the experiments, (C57BL/6×C3/He) F1 ~~mouse~~mice of 5-week-old were~~as~~ immunized in advance by the ~~administration of~~ering the virus for immunological treatment, and twelve weeks later, ovarian cancer cells OVHM were subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 cells per mouse to form a 5~~-~~10 mm tumor~~.~~. Then, A549 cells (Ad-A549) infected with the above mentioned adenovirus

AdE3-1A1.3B at a ~~rate~~concentration of 250 vp/cell were administered into the tumor~~.~~. A non-proliferative adenovirus having no E1 gene was used as the virus for immunological treatment, more specifically, adenovirus Ad-β-gal with an inserted LacZ gene ~~at the~~ downstream of the CMV promoter, without inactivation by UV irradiation, was used and intracutaneously administered at a ~~rate~~concentration of 1×10^{10} vp per mouse~~.~~. The carrier cells, A549 cells, were irradiation-treated at a dose of 200 Gy and were administered into the tumor of the mouse at a ~~rate~~concentration of 5×10^{6} cells per treatment~~,~~once and six times in total.

~~[0114]~~ The results of the above experiment are shown in ~~Fig.~~Figures 18 (a) and (b)~~.~~. In each graph, "Ad-β-gal→Ad-A549" shows ~~represents~~ the results of the above mentioned experiment, "Ad-A549" shows ~~represents~~ the results of administration-offering only the carrier cells, "Ad-β-gal" shows~~represents~~ the results of administration-offering only the Ad-β-gal for treatment (not as the virus for immunological treatment), and "control" shows ~~represents~~ the results of administration-offering PBS buffer~~.~~. Number (n) of mice in each group was~~having~~ five animals ~~is shown by n=5.~~. Figure 18 ~~The graph~~ (a) shows the ~~observed results of~~ tumor volume in ~~of~~ each mouse for a comparatively short period and Figure 18 ~~graph~~ (b) shows the ~~observed results of~~ survival rate of the mice~~mouse~~ in each group for a long period~~.~~. As shown by these figures~~graphs~~, a potent *in vivo* antitumor effect was observed in "Ad-β-gal→Ad-A549".

~~The [0115] Administration~~ interval between administration-offering the adenovirus for immunological treatment and ~~that of~~ the carrier cell was investigated~~.~~. This experiment was ~~similarly~~ carried out similar to ~~as~~ that in ~~Fig.~~Figure 18, except for the various changes in~~of~~ the ~~administration~~ intervals of administration and infection of adenovirus AdE3-1A1.3B with carrier A549 cell at 50 vp/cell.

The results of the above mentioned experiments are shown in ~~Fig.~~Figures 19 (a) and (b)~~.~~. In each figure~~graph~~, "2-4w", "5-9w", "10-15w" and "16-22w" show ~~represent~~ the results of experiments with above mentioned administration intervals of 2~~-~~-4 weeks, 5~~-~~-9 weeks, 10~~-~~-15 weeks and 16~~-~~-22 weeks, respectively~~.~~. Number (n) of mice in each group was~~having~~ five animals ~~is shown by n=5.~~. As shown by these Figures, the best antitumor effect was obtained when the above mentioned administration interval was set at 10~~-~~-15 weeks~~.~~. As shown by the present experiments, when the adenovirus Ad-β-gal, without inactivation, was~~is~~ administered as the virus for immunological treatment, the CTL reaction by T cells was~~is~~ considered to become

predominant at about 10 - 15 weeks after the administration, compared with the suppression of infection due to neutralizing antibodies.

The [0116] Aabove mentioned administration interval is preferpreferredably to be short in consideration of the clinical application. Then, it was investigated whether the above mentioned administration interval couldan be made shortened by the usinge of inactivated adenovirus Ad-β-gal as the virus for immunological treatment was investigated. As shown in Fig.Figure 20, it was found that when the UV inactivated adenovirus UV-Ad-β-gal by UV irradiation was used as the virus for immunological treatment, the above mentioned administration interval ofset at four weeks or three weeks showeds favorable antitumor effects, that is, inactivation of the virus for immunological treatment can be shortened to an the above mentioned administration interval ofto about 3 - 4 weeks.

The [0117] Aabove mentioned experiments were similarly carried out similar to those of experiments shown in Fig.Figure 18, except for the following points; inactivated adenovirus UV-Ad-β-gal was used as the virus for immunological treatment, the above UV-Ad-β-gal was intracutaneously administered at a rateconcentration of 1×10^7 vp per mouse, the above mentioned administration intervals were set to three weeks, four weeks, five weeks or six weeks, and the carrier A549 cell was infected with the adenovirus AdE3-1A1.3B at a rateconcentration of 50 vp/cell. Number (n) of mice in each group washaving 10 animals is shown by n=10.

[0118] Fig.Figure 21 shows the results of investigation of virus dosage of the virus when above mentioned UV-Ad-β-gal was used as the virus for immunological treatment. In this experiment, the rateconcentration of the UV-Ad-β-gal was changed toin a range of 1×10^6 vp to 1×10^{11} vp. The experiment was carried out similar to ly with that shown in Fig.Figure 20, except the for above mentioned administration interval was set at six weeks. The result showed that the rateconcentration of UV-Ad-β-gal set at 1×10^7 vp gave the best antitumor effect. (From this result, the rateconcentration of UV-Ad-β-gal was set at 1×10^7 vp in the experiment shown in Fig.Figure 20).

[0119] Fig.Figures 22 (a) and (b) show the results of investigation of effect of tumor immunization (tumor vaccination). The Aabove mentioned UV-Ad-β-gal was intracutaneously administered at a rateconcentration of 1×10^7 vp per mouse, and after 10 days, for tumor vaccination, irradiated ovarian cancer cells OVHM were subcutaneously transplanted at a rateconcentration of 1×10^6 cells. Simultaneously, squamous ep. cancer cells SCC7 or ovarian

cancer cells OVHM were subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 cells. Then, AdE3-1A1.3B infected A549 cells were administered six times at a ~~rate~~concentration of 5×10^6 cells ~~per to~~ mouse~~ice six times~~ into a formed 5 - 10 mm tumor (in the ~~Fig.~~Figure, shown by "OVHM-RT+Ad-β-gal→SCC7" and "OVHM-RT+Ad-β-gal→OVHM"). The ~~administered~~ treated mice ~~mouse~~ showed a marked inhibition of tumor growth and proliferation in comparison to the control group. ~~(~~In the ~~Fig.~~Figure, "SCC7" ~~represent~~shows SCC7 tumor treated by the carrier cell without tumor vaccination, and "OVHM" ~~represent~~shows OVHM tumor treated by the carrier cell without tumor vaccination~~)~~. Especially, ~~by~~ the tumor vaccination with irradiated OVHM followed by the carrier cell treatment, showed the formed OVHM tumor completely disappeared in all mice without recurrence.

~~[0120]~~ ~~Fig.~~Figure 23 shows the ~~results of investigation of~~ tumor vaccination with non-small-cell lung cancer A549 cells. In this experiment, irradiated A549 cells infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 100 vp/cell were subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 cells per mouse. After 40 days, ovarian cancer cells OVHM were subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 cells. The mice (in the ~~Fig.~~Figure, "AdE3-1.3B-infected A549→OVHM") also showed marked inhibition of tumor growth and proliferation in comparison to the control group (in the ~~Fig.~~Figure, "OVHM" ~~represent~~shows OVHM tumor treated by the carrier cell without tumor vaccination) with marked improvement in survival rate.

~~[0121]~~ The above mentioned results show that the antitumor effect can be obtained even by tumor vaccination with different kinds of cancer cells.

~~[0122]~~ Then, the effect of administration of~~ering~~ atelocollagen together with the carrier cell was investigated. In this experiment, A549 cells infected with a predetermined amount of adenovirus AdE3-1A1.3B were administered to 5- to 10-week-old (C57BL/6×C3/He) F1 ~~mouse~~mice at a ~~rate~~concentration of 5×10^6 cells with ~~by mixing~~ atelocollagen ~~at a to make~~ final concentration of 0.1%. ~~, and I~~It was investigated whether the treatment decreased the death rate caused by the side effect due to the administration of~~ering~~ the adenovirus ~~was improved.~~ The results are shown in ~~Fig.~~Figure 24. In the ~~Fig.~~Figure, ~~a~~the right bar shows ~~represent~~s the results of administration of~~ering~~ atelocollagen together with adenovirus AdE3-1.3B infected A549 cells at a ~~rate~~concentration of 50 vp/cell or 250 vp/cell. The ~~L~~left and central bars ~~represent~~show the results of administration of~~ering~~ adenovirus AdE3-1.3B infected A549 cells at

a ~~rate~~concentration of 5 vp/cell and 50 vp/cell, respectively (no atelocollagen is mixed). As shown in the ~~Fig.~~Figure, simultaneously ~~administration of~~ering atelocollagen dramatically reduced the death rate caused by the side effects and the administration dose can be increased. This may be caused by the inhibition of adenovirus dispersion and the blockage of anti-adenovirus neutralizing antibodies~~y~~ by the atelocollagen.

[0123] ~~As~~ As shown above, simultaneously ~~administration of~~ering atelocollagen and carrier cells suppressed the side effect and a high dose administration of adenovirus became possible.

[0124] ~~Next,~~ Next, the adenovirus Ad-β-gal without inactivation treatment was administered once, twice or 3 ~~times~~thrice into a mouse~~,~~ to increase the anti-adenovirus antibodies~~y~~ in the blood by the booster effect~~.~~. After that, the antitumor effect was investigated in each mouse~~.~~. In this experiment, adenovirus Ad-β-gal was administered once, twice or 3 ~~times~~thrice ~~administered~~ to 5-week-old (C57BL/6×C3/He) F1 ~~mouse~~mice (administration at every four weeks at a ~~rate~~concentration of 1×10^{10} vp), thereafter, ovarian cancer cells OVHM were subcutaneously transplanted at a ~~rate~~concentration of 1×10^{6} cells per mouse to form 5~~-~~ 10 mm tumor and irradiated carrier cells were administered into the tumor~~.~~. A549 cells, optionally mixed with 293 cells, were used as the carrier cells.

[0125] ~~In~~ In case of mixtures of A549 cells and 293 cells, A549 cells infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 50 vp/cell were administered at a ~~rate~~concentration of 3.75×10^{6} cells, and 293 cells infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 10 vp/cell were administered at a ~~rate~~concentration of 3.75×10^{6} cells, respectively, into the tumor at each ~~for one~~ administration~~.~~. These two kinds of carrier cells were administered six times in total~~.~~. The results are shown in ~~Fig.~~Figures 25 (a) and (b)~~.~~. In the case of ~~administration of~~ering only A549 cells, A549 cells infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 50 vp/cell were administered at a ~~rate~~concentration of 7.5×10^{6} cells per mouse into the tumor at each~~for one~~ administration~~.~~. The carrier cells were administered six times in total~~.~~. The results are shown in ~~Fig.~~Figures 26 (a) and (b)~~.~~. In ~~the Fig.~~Figure 25 and ~~Fig.~~Figure 26, "×1", "×2" and "×3" ~~represent~~show the results of administering adenovirus Ad-β-gal once, twice and 3 ~~times~~thrice ~~administrations of adenovirus Ad-β-gal~~, respectively~~.~~. As shown in these figures, the carrier cells showed antitumor effect even in anti-adenovirus antibody positive ~~mice~~ouse, caused by the several administrations of adenovirus Ad-β-gal~~.~~. The mixture of A549 cells and 293 cells used as the carrier cells showed superior

results to that of administration ofering only A549 cells.

[0126] Fig.Figures 27 (a) and (b) show the results of investigation of *in vivo* antitumor effect by administration ofering carrier cells (A549 cells) infected with not only adenovirus AdE3-1A1.3B and but also GM-CSF expression vector, and further together with atelocollagen. In this experiment, adenovirus Ad-β-gal was administered once, twice or 3 timesthrice (every four weeks at a rateconcentration of 1×10^{10} vp) into 5-week-old (C57BL/6×C3/H3) F1 mousemice in a similar manner with the experiment shown in Fig.Figure 26.

Then, ovarian cancer cells OVHM were subcutaneously transplanted at a rateconcentration of 1×10^{10} cells per mouse. After formation of a 5 - 10 mm diameter tumor with 5-10 mm diameter, irradiated carrier cells (A549 cells) were administered into the tumor. The carrier cells were infected with adenovirus AdE3-1A1.3B at a rateconcentration of 50 vp/cell and a GM-CSF expression vector (a vector with an inserted a GM-CSF gene at the adenovirus E1 gene deficient site and at the downstream of the CMV promoter) at a rateconcentration of 10 vp/cell. The prepared irradiated A549 cells were administered in into the tumor at a rateconcentration of 7.5×10^{6} cells, together with atelocollagen (concentration at 0.1%), for one each administration. These were three times (×3) administered three times in total.

[0127] In Fig.Figures 27 (a) and (b), "Ad-β-gal→AdE3-1A1.3B+GMCSF" representshows the results of the above mentioned experiment, "Ad-β-gal→AdE3-1A1.3B" representshows the results of six times (×6) administrations of carrier cells (A549 cells) infected with adenovirus AdE3-1A1.3B at a rateconcentration of 50 vp/cell into the tumor at a rateconcentration of 7.5×10^{6} cells for eachone administration. As shown in the Figure, three times administrations of "AdE3-1A1.3B+GMCSF" showed a more potent *in vivo* antitumor effect than that of six times administrations of "AdE3-1A1.3B", in all administrations of once, twice and 3 timesthrice administrations of adenovirus Ad-β-gal.

The [0128] Aabove results showed that infection of not only the oncolytic adenovirus and but also GM-CSF expression vector to the carrier cells wais very effective in cancer therapy.

[0129] Fig.Figures 28 (a) and (b) show the results of investigation of effect of intraperitoneal administration of an iron preparation at the time of carrier cell administration. In this experiment, adenovirus Ad-β-gal was administered once, twice or 3 timesthrice administered (every four weeks at a rateconcentration of 1×10^{10} vp for eachone administration) to 5-week-old (C57BL/6×C3/He) F1 mousemice. Then ovarian cancer cells OVHM were

subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 cells per mouse~~.~~. After formation of a 5 - 10 mm diameter tumor ~~with 5-10 mm diameter~~, irradiated carrier cells were administered into the tumor~~.~~. A549 cells infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 50 vp/cell were used as the carrier cells and administered at a ~~rate~~concentration of 7.5×10^6 cells for each~~one~~ administration~~.~~. At the time of administering the carrier cell ~~administration~~, 0.01 mg of iron dextran (Fe-Dextran) was intraperitoneally administered as an iron preparation~~.~~. These were ~~three times (×3)~~ administered three times (×3) in total (the iron preparation was also administered at~~in~~ every occasion).

[0130] In ~~Fig.~~Figures 28 (a) and (b), "Ad-β-gal→AdE3-1A1.3B+Fe" ~~represent~~shows the results of the above experiment~~.~~. "Ad-β-gal→AdE3-1A1.3B" ~~represent~~shows the results of six ~~times~~ (×6) administrations of carrier cells (A549 cells) infected with adenovirus AdE3-1A1.3B at a ~~rate~~concentration of 50 vp/cell in the tumor at a ~~rate~~concentration of 7.5×10^6 cells for each~~one~~ administration~~.~~. As shown in the Figure, three ~~times~~ administrations of "AdE3-1A1.3B+Fe" showed a more potent *in vivo* antitumor effect than ~~that of~~ six ~~times~~ administrations of "AdE3-1A1.3B" (in which case, only the carrier cells were~~as~~ administered), in all 1~~once~~, 2~~twice~~ and 3~~thrice~~ administrations of adenovirus Ad-β-gal.

The [0131] A~~a~~bove results showed that a combined administration of~~ering~~ the carrier cell with an iron preparation is very effective in cancer therapy.

[0132] Then, the~~a~~ radiation dose in the radiation exposure treatment to the carrier cells before administration was investigated~~.~~. In the experiment, 5-week-old nude mice were~~ouse was~~ used and A549 cells were irradiated at different doses and then subcutaneously transplanted at a ~~rate~~concentration of 1×10^7 cells per mouse, and the formation and growth of the tumor was observed~~.~~. The results are shown in ~~Fig.~~Figure 29~~.~~. As shown in the Figure, formation and growth of the tumor was inhibited by setting the radiation dose at 120 Gy or over.

[0133] In an experiment using (C57BL/6×C3/He) F1 ~~mouse~~mice, ~~Fig.~~Figure 30 shows the ~~results of investigation of~~ antitumor effect when the carrier cells (A549 cells) were treated by radiation with various doses~~.~~. In this experiment, adenovirus UV-Ad-β-gal was administered to 5-week-old (C57BL/6×C3/He) F1 ~~mouse~~mice at a ~~rate~~concentration of 1×10^{10} vp~~.~~. After five weeks, the ovarian cancer cells OVHM were subcutaneously transplanted at a ~~rate~~concentration of 1×10^6 per mouse~~.~~. After formation of a 5 - 10 mm diameter tumor ~~with 5-10 mm diameter~~, carrier cells irradiated at a dose of 50 Gy, 100 Gy, 200 Gy or 400 Gy were administered into the

tumor. A549 cells infected with adenovirus AdE3-1A1.3B at a rate concentration of 50 vp/cell were used as the carrier cells and administered at a rate concentration of 7.5×10^6 cells for each one administration. The carrier cells were administered six times administered in total. The results showed a more favorable result at a radiation dose of 400 Gy than that at a radiation dose of 200 Gy.

[0134] Fig. Figure 31 shows the results of investigation for the amount of infection of the oncolytic virus to the carrier cell. In this experiment, adenovirus Ad-β-gal was administered to 5-week-old (C57L/6×C3/He) F1 mouse at a rate concentration of 1×10^{10} vp. After four weeks, ovarian cancer cells OVHM were subcutaneously transplanted at a rate concentration of 1×10^6 cells. After formation of a 5 - 10 mm diameter tumor with 5-10 mm diameter, carrier cells (A549 cells) irradiated at a dose of 250 Gy were administered into the tumor. The amount of infection of adenovirus AdE3-1A1.3B to the carrier cell was set at 100 vp/cell, 250 vp/cell or 500 vp/cell. The carrier cells were administered at a rate concentration of 7.5×10^6 cells for each one administration. Together with the carrier cell administration, atelocollagen (concentration 0.1%) was concurrently administered in the tumor. These were administered six times administered in total. The results showed most favorable result at the infection rate concentration of 250 vp/cell, and found that rate concentrations of 150- - 400 vp/cell gave favorable results.

[0135] Fig. Figures 32 (a) and (b) show the results of investigation of effect of tumor vaccination in a similar experiment to that shown in Fig. Figure 31. In this experiment, adenovirus Ad-β-gal was administered to 5-week-old (C57L/6×C3/He) F1 mouse mice at a rate concentration of 1×10^{10} vp. After four weeks, for tumor vaccination, ovarian cancer cells OVHM-RT irradiated at a dose of 80 Gy were as subcutaneously transplanted at a rate concentration of 1×10^6 cells. Then, ovarian cancer cells OVHM were subcutaneously transplanted at a rate concentration of 1×10^6 cells. After formation of a 5 - 10 mm diameter tumor with 5-10 mm diameter, carrier cells treated irradiated at a dose of 250 Gy were as administered into the tumor. A549 cells infected with adenovirus AdE3-1A1.3B at a rate concentration of 50 vp/cell were used as the carrier cells and administered at a rate concentration of 7.5×10^6 cells for each one administration. Together with the carrier cell administration, atelocollagen (concentration 0.1%) was concurrently administered in the tumor. These were administered three times administered in total. The results showed marked

inhibition of tumor growth and proliferation in the mouse with tumor vaccination (in the ~~Fig.~~ Figure, "OVHM-RT→A549") in comparison to the mouse without tumor vaccination (in the ~~Fig.~~ Figure, "A549"). The survival rate was also greatly improved.

The ~~[0136]~~ Above results show that the use of tumor vaccination provides a favorable antitumor effect together with the use of the cancer gene therapeutic drug of the present ~~invention~~disclosure.

Industrial applicability

~~[0137]~~ As described above, the cancer gene therapeutic drug of the present ~~invention~~disclosure can be applied to almost all malignant tumors and can be expected to exhibit potent antitumor effect including ovarian cancer, squamous epithelium cancers (e.g. uterine cervix cancer, cutaneous carcinoma, head and neck cancer, esophageal cancer and lung cancer), digestive tract cancers (e.g. colon~~ic~~ cancer, pancreatic cancer, hepatic cancer and gastric cancer), neuroblastoma, cerebral tumor, mammary cancer, testicular cancer and prostatic cancer.